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IMPACT STUDY

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Air Resources Final Report

Principal Authors

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Air Quality Bureau
Environmental Sciences Division
Department of Health and Environmental Sciences
Helena, Montana 59620

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TABLE OF CONTENTS

	<u>Page</u>
List of Tables	i
List of Figures	iii
Introduction	1
Ambient Air Quality	7
A. General Methodology	7
B. Particulates	7
1. Moose City	9
2. Polebridge	10
3. Columbia Falls-NAAC	11
4. Columbia Falls - Anders	11
5. Whitefish	12
6. Kalispell - GIA	13
7. Kalispell - Strom	13
8. Kalispell - Universal Athletics	14
9. Kalispell - Evergreen	14
10. Bigfork	15
11. Polson	16
12. Ronan	16
13. Ninepipe	17
14. Swan River Youth Camp	17
C. Sulfates and Nitrates	18
D. Visibility	19
Meteorology	47
A. General Methodology	47
B. Surface Wind	47
1. Big Prairie	47
2. Glacier International Airport	48
3. Bigfork	49
4. Polson	49
5. Ninepipe	50
Emission Inventory	111
A. General Methodology	111
1. Point Sources	111
2. Nonpoint Sources	112
B. Results of the Emission Inventory	112
1. Particulates	112
2. Sulfur Dioxide	114
3. Other Pollutant Sources	115

	<u>Page</u>
Atmospheric Diffusion Modeling	119
A. Background	119
B. Preliminary Assessment to Develop a Modeling Study Plan . .	119
1. General Procedures	119
2. Option Development	121
3. Analysis of Options and Selection of the Optimum Alternative	121
C. Diffusion Modeling Analysis	127
1. Preparation of Meteorological Data	127
a. Data Assessment	127
b. Methods to Handle Missing Data	128
c. Data Completeness.	129
d. Stability Frequency Decks	129
e. Preprocessed Hourly Data Decks	129
f. Delineation of Airsheds	129
g. Model Selection	130
2. Modeling Results	132
a. North Fork	132
b. Other Airsheds	135
3. Model Evaluation	137
4. Modeling Summary	139
Project Summary	163

LIST OF TABLES

	<u>Page</u>
1-A Flathead Basin TSP Levels	23
2-A Moose City Particulate, Sulfate and Nitrate Data	24
2-B Polebridge Particulate, Sulfate and Nitrate Data	25
2-C Columbia Falls - NAAC Particulate, Sulfate, and Nitrate Data	26
2-D Columbia Falls - Anders Particulate, Sulfate and Nitrate Data	27
2-E Whitefish Particulate, Sulfate, and Nitrate Data	28
2-F Glacier International Airport Particulate, Sulfate and Nitrate Data	29
2-G Kalispell - Strom Particulate, Sulfate, Nitrate Data	30
2-H Kalispell-Universal Athletics Particulate, Sulfate, Nitrate Data	31
2-I Kalispell-Evergreen Particulate Data	32
2-J Bigfork Particulate, Sulfate and Nitrate Data	33
2-K Polson Particulate, Sulfate and Nitrate Data	34
2-L Ronan Particulate, Sulfate and Nitrate Data	35
2-M Ninepipe Particulate, Sulfate and Nitrate Data	36
2-N Tribal Particulate Data for Ronan, St. Ignatius, Arlee and Evaro	37
2-O Swan River Youth Camp Particulate, Sulfate, Nitrate Data .	38
3-A Polebridge Fine Particulate Data	39
3-B Columbia Falls - Anders Fine Particulate Data	40
3-C Kalispell-Airport Fine Particulate Data	41
3-D Kalispell-Universal Athletics Fine Particulate Data	42
3-E Polson Fine Particulate Data	43
3-F Ninepipe Fine Particulate Data	44
4-A Kalispell - Airport Visibility Data	45
4-B Ninepipe Visibility Data	46
5-A Point Source Emission Estimates	116
6-A Flathead Basin Area Source Emission Inventory Summary . . .	118
7-A Flathead Study Diffusion Modeling Options	142
8-A General Meteorological Data Periods	146
9-A Meteorological Data Recovery and Source - Big Prairie . . .	147
9-B Meteorological Data Recovery and Source - Columbia Falls .	148
9-C Meteorological Data Recovery and Source - Glacier Inter- national Airport	149
9-D Meteorological Data Recovery and Source - Bigfork	150
9-E Meteorological Data Recovery and Source - Polson	151
9-F Meteorological Data Recovery and Source - Ninepipe	152
10-A Emission Rates - Proposed Cabin Creek Coal Mine	153
11-A North Fork Box Model Results - Predicted Increases in Con- centrations from the Proposed Cabin Creek Coal Mine. . .	153
12-A North Fork Valley Model Results - Predicted Increases in Concentrations from Proposed Cabin Creek Coal Mine . . .	154
13-A Hypothetical North Fork Gas Flares - Sulfur Dioxide Emission Parameters	154
14-A North Fork Valley and Box Model Results - Annual and Twenty Four Hour Sulfur Dioxide Concentrations - Hypothetical Gas Flares	154

List of Tables, Continued

		<u>Page</u>
15-A	ISCLT Model Results, Run 1 - Annual Particulate Concentra- tions - Measured vs. Predicted	155
16-A	ISCST Model Results, Run 1 - Kalispell Airshed, Twenty Four Hour Concentrations - Measured vs. Predicted. . . .	156
17-A	Summary of ISCST Model Results, Run 1 - Twenty Four Hour Concentrations - Average Measured Value vs. Average Predicted Value	158
18-A	ISCLT Model Results, Run 2 - Annual Particulate Concentra- tions - Measured vs. Predicted	158
19-A	Residual Measure of Accuracy - Annual Concentrations . . .	159
20-A	Residual Measure of Accuracy- Twenty Four Hour Concentra- tions	159
21-A	Performance Measure for Gross Variability - Twenty Four Hour Concentration	160
22-A	Student's "t" Test Results	161
23-A	Linear Regression and Correlation Results	162

LIST OF FIGURES

	<u>Page</u>
1-A Flathead River Basin Study Map	20
2-A Three Year Plot of TSP at Kalispell - Universal Athletics	21
2-B Three Year Plot of TSP at Columbia Falls - Anders Residence	22
3-A Monthly Wind Roses for Big Prairie - June, July, August and September, 1980	51
3-B Monthly Wind Roses for Big Prairie - October and November, 1980	52
3-C Quarterly Wind Roses for Big Prairie - July through September and October through November 1980	53
3-D Annual Wind Rose for Big Prairie - 1980	54
3-E Monthly Wind Roses for Big Prairie - March, April, May and June, 1981	55
3-F Monthly Wind Roses for Big Prairie - July, August, September and October 1981	56
3-G Quarterly Wind Roses for Big Prairie - April through June, July through September, and October 1981	57
3-H Annual Wind Rose for Big Prairie - 1981	58
3-I Monthly Wind Roses for Big Prairie - March, April, May and June 1982	59
3-J Quarterly Wind Roses for Big Prairie - January through March and April through June, 1982	60
3-K Annual Wind Rose for Big Prairie - 1982	61
4-A Monthly Wind Roses for Glacier International Airport - January, February, March and April 1980	62
4-B Monthly Wind Roses for Glacier International Airport - May, June, July and August 1980	63
4-C Monthly Wind Roses for Glacier International Airport - September, October, November and December 1980	64
4-D Quarterly Wind Roses for Glacier International Airport - January through March, April through June, July through September and October through December 1980	65
4-E Annual Wind Rose for Glacier International Airport -1980	66
4-F Monthly Wind Roses for Glacier International Airport - April, July, August and September 1981	67
4-G Monthly Wind Roses for Glacier International Airport - October, November and December 1981	68
4-H Quarterly Wind Roses for Glacier International Airport - July through September and October through December 1981	69
4-I Annual Wind Rose for Glacier International Airport - 1981	70
4-J Monthly Wind Roses for Glacier International Airport - January, February, March and April 1982	71
4-K Monthly Wind Roses for Glacier International Airport - May, June, July and August 1982	72
4-L Monthly Wind Roses for Glacier International Airport - September, October, November and December 1982	73
4-M Quarterly Wind Roses for Glacier International Airport - January through March, April through June, July through September and October through December 1982	74
4-N Annual Wind Rose for Glacier International Airport - 1982	75

5-A	Monthly Wind Roses for Bigfork - January, February, March, and April 1980	76
5-B	Quarterly Wind Rose for Bigfork - January through March 1980	77
5-C	Annual Wind Rose for Bigfork - 1980	78
5-D	Monthly Wind Roses for Bigfork - July, August, September and October, 1981	79
5-E	Monthly Wind Roses for Bigfork - November and December 1981	80
5-F	Quarterly Wind Roses for Bigfork - July through September and October through December 1981	81
5-G	Annual Wind Rose for Bigfork 1981	82
5-H	Monthly Wind Roses for Bigfork - January, February, March and April 1982	83
5-I	Monthly Wind Roses for Bigfork - May, June, July and August 1982	84
5-J	Monthly Wind Roses for Bigfork - September, October, November, and December 1982	85
5-K	Quarterly Wind Roses for Bigfork - January through March, April through June, July through September, and October through December 1982	86
5-L	Annual Wind Rose for Bigfork - 1982	87
6-A	Monthly Wind Rose for Polson - February, June, July and August 1980	88
6-B	Monthly Wind Rose for Polson - September 1980	89
6-C	Annual Wind Rose for Polson - 1980	90
6-D	Monthly Wind Roses for Polson - March, April, May and June 1981	91
6-E	Monthly Wind Roses for Polson - July, August, September, and October, 1981	92
6-F	Monthly Wind Rose for Polson - November 1981	93
6-G	Quarterly Wind Roses for Polson - April through June, July through September, and October through December 1981	94
6-H	Annual Wind Rose for Polson - 1981	95
6-I	Monthly Wind Roses for Polson - April, May, July and August 1982	96
6-J	Monthly Wind Roses for Polson - September, October, November and December 1982	97
6-K	Quarterly Wind Roses for Polson - April through June, July through September, and October through December 1982	98
6-L	Annual Wind Rose for Polson - 1982	99
7-A	Monthly Wind Rose for Ninepipe - December 1980	100
7-B	Monthly Wind Roses for Ninepipe - January, February, March and April 1981	101
7-C	Monthly Wind Roses for Ninepipe - May, June, July and August 1981	102
7-D	Monthly Wind Roses for Ninepipe - September, October, November and December 1981	103

	<u>Page</u>
7-E	Quarterly Wind Roses for Ninepipe - January through March, April through June, July through September, and October through December 1981
	104
7-F	Annual Wind Rose for Ninepipe - 1981
	105
7-G	Monthly Wind Roses for Ninepipe - January, February, March and April 1982
	106
7-H	Monthly Wind Roses for Ninepipe - May, June, July and August 1982
	107
7-I	Monthly Wind Roses for Ninepipe - September, October, November and December 1982
	108
7-J	Quarterly Wind Roses for Ninepipe - January through March, April through June, July through September, and October through December 1982
	109
7-K	Annual Wind Rose for Ninepipe - 1982
	110
8-A	Sample Point Source Emission Inventory Printout
	116
9-A	Flathead Basin, Area Source Emission Inventory, Grid Index
	117
10-A	Flathead Basin Study Area and Airshed Map
	141

INTRODUCTION

Recognizing the need to protect the high quality environment of the Flathead River Basin, Congress in 1977 directed the Environmental Protection Agency (EPA) to study possible environmental impacts of resource development in the Flathead River Basin. In response the EPA cooperated with state and local government bodies and interested individuals to establish the Flathead River Basin Environmental Impact Study.

The Flathead Study was directed by a 15-member Steering Committee composed of a representative of EPA, state government, the Confederated Salish-Kootenai Tribal Council, local governments, area citizens, and several federal agencies. The overall goal of the Steering Committee, and of the Flathead Study itself, was to provide a data base to help citizens, government and industry in the Flathead River Basin make decisions concerning the environment. More specifically, the Study was to develop the analytical ability to assess potential impacts and provide necessary management tools to control the various levels, types, and locations of developmental activity.

The Air Quality Bureau (AQB) of the Department of Health and Environmental Sciences was requested by the Steering Committee early in 1978 to assess the need for additional air quality studies and prepare a proposal for the air quality work. The AQB identified five specific goals or needs for the Flathead Basin air quality studies. These goals were:

1. To quantify the existing air quality within the Basin;
2. To identify existing levels and sources of air pollution which affect the Basin;
3. To quantify the meteorology of the Basin at both low and high altitudes;

4. To develop the capability to assess the effects of man's activities upon the air quality of the Basin; and

5. To develop guidelines to protect and enhance the air quality of the Basin.

A brief chronology of the study's progress follows:

During the initial year of study, June 1978 through June 1979, the upper air meteorological system that had been operating at the Glacier International Airport (GIA) was incorporated into the study. Two surface wind stations were installed and operated in the area. A contracting meteorologist was hired to handle the instrument operation and data analysis. During 1978 the following sites were monitored with the samplers listed.

Moose City (Canadian border) (see Figure 1-A)

- high volume sampler (total suspended particulate, sulfate and nitrate)

Polebridge

- dichotomous sampler (particulate sizing instrument)
- surface wind station
- temperature

Kalispell--Glacier International Airport (GIA)

- pilot balloon program (upper level wind flow)
- temperature sonde system (inversion heights and temperature lapse rate)
- acoustic sounder (relative stability, mixing heights, and inversion heights)
- surface meteorological system (pressure, wind, temperature and dewpoint)
- nephelometer (visibility)
- pyranometer (two wavelengths - total solar radiation)
- pyrhelimeter (two wavelengths - direct solar beam)
- dichotomous sampler

Ronan

- high volume sampler

Polson

- dichotomous sampler
- surface wind system

Several other AQB monitoring sites continued to be operated:

Columbia Falls area

- high volume samplers (two)
- surface wind system

Kalispell

- high volume sampler

During 1979 the various samplers installed during 1978 continued to operate except for the high volume air sampler at Moose City, which was shut down due to the lack of easy access and power. In addition high volume air samplers were installed at the Glacier International Airport, Polson, and Bigfork sites, and particle size instruments were installed adjacent to the high volume samplers in Kalispell and Columbia Falls. These instruments provided valuable data on the amount of respirable and non-respirable suspended particulate in the air. In November 1979 the surface wind system at Columbia Falls was moved to Bigfork. A report that summarized the data collected through June 1979 was prepared in September of 1979.

In 1980 data collection continued at all sites. The pyrheiliometers at GIA were removed, the Kalispell-Strom site sampler was re-located to the Universal Athletics building, and a new high volume air sampler site was installed in the Evergreen area between Kalispell and the Airport. A second upper air monitoring site with pilot balloons, temperature sondes, an acoustic sounder, and a surface wind system was installed at Ninepipe National Wildlife Refuge near Ronan in the

fall of 1980. Pilot balloon releases commenced January 5, 1981. A high volume sampler and a dichotomous sampler were also installed at the site. The Ninepipe site was being operated in cooperation with the Salish-Kootenai Tribal Air Quality Department. The upper air information collected at the Ninepipe site allowed comparisons to be made between the northern and southern ends of the Basin.

A detailed inventory of area and point sources of particulate and SO₂ air pollution in the Basin was prepared. The source emission inventory was submitted to the Steering Committee in June 1980.

A report summarizing data through September, 1980 was presented to the Steering Committee in June, 1981.

During 1981 the dichotomous sampler at Polebridge was replaced with a high volume air sampler and an additional high volume air sampler was installed in Whitefish.

The 1981 sampling network included:

Polebridge

- surface wind system with temperature
- high volume air sampler

Columbia Falls

- two high volume air samplers
- dichotomous sampler

Whitefish

- high volume air sampler

Glacier International Airport (GIA)

- pilot balloon program
- temperature sonde system
- acoustic sounder

- surface wind system with temperature
- nephelometer
- pyranometers (two wavelengths)
- high volume air sampler
- dichotomous sampler

Evergreen

- high volume air sampler

Kalispell

- high volume air sampler
- dichotomous sampler

Bigfork

- high volume air sampler
- surface wind system with temperature

Polson

- high volume air sampler
- dichotomous air sampler
- surface wind system with temperature

Ninepipe Wildlife Refuge

- pilot balloon program
- temperature sonde system
- acoustic sounder
- nephelometer
- surface wind system
- high volume air sampler
- dichotomous sampler

During 1982 a new high volume air sampler was set up at the Swan River Youth Camp while the dichotomous samplers were removed from all the Flathead Basin

monitoring sites. The meteorological sensors at the Big Prairie site were removed in June of 1982 and the upper air studies at the Glacier International Airport were discontinued as of July 1, 1982. The rest of the sampling network remained the same in 1982.

During 1983 a second high volume air sampler was set up in Kalispell and the rest of the system was gradually dismantled. Only those air monitoring sites which were part of the AQB's regular air monitoring network were retained. As of July, 1983, samplers in the Basin included:

Columbia Falls

- high volume air sampler

Kalispell

- two high volume air samplers

During 1982 and 1983 a modeling study was initiated to use the data collected to predict impacts of future developments in the Basin. During the first phase of the modeling study a contractor was hired to evaluate the data collected and the various models available in order to recommend a preferred modeling procedure. During the second phase of the modeling study, the meteorological data was pre-processed into formats easily accessible by the EPA Gaussian models. Predictive models were run for each airshed in the Basin.

This report includes summaries of all the air quality data collected through December 1982, analysis of the meteorological data collected at each site, emission inventory summaries and a summary of the results of the modeling study.

AMBIENT AIR QUALITY

A. General Methodology

The first goal of the air quality portion of the Flathead Basin Environmental Impact Study was to quantify the existing air quality within the Basin. The Air Quality Bureau accomplished this goal by installing and operating an extensive network of several types of particulate and visibility monitors. The Department purchased the sampling equipment and supported the network by providing supplies, repair services, spare parts, training and laboratory services. The actual performance of the day to day network operation was accomplished by private contractors.

B. Particulates

Two methods of particulate monitoring were used in the Flathead Basin Study. They were the high volume air sampler and the dichotomous sampler. The high volume air sampler is generally used to measure total suspended particulate, while the dichotomous sampler measures smaller particulate in two size ranges.

The first method (high volume) draws ambient air through a preweighed glass fiber filter at a known rate of flow for twenty four hours (from midnight to midnight) every sixth day. The filter is reweighed after exposure and the difference between the final weight and tare weight of the filter is divided by the volume of air sampled to calculate the concentration of particulate in micrograms per cubic meter. The filter used is highly efficient for particles down to .01 microns. The construction of the high volume sampler shelter imposes an upper size limit of 200 microns barring wind effects, and has a 50 percent cut-off for 40 micron particles. This large size range of collected particulates that were suspended in the air (or falling relatively slowly) is the

basis of the term "total suspended particulate". Total suspended particulate (TSP) levels were monitored at five sites in the Basin in 1978, at eight sites in 1979, at nine sites in 1980, at ten sites in 1981 and at eleven sites in 1982 (Table 1-A). In addition, results from four tribal sampling sites are included in this report. Figure 1-A is a map showing the locations of the sampling sites used in the Flathead Basin Environmental Impact Study.

Table 1-A summarize the TSP levels at all sites for the years 1978, 1979, 1980, 1981 and 1982. The values listed for each site are highest and second highest 24-hour levels for the year and the arithmetic average. The data clearly shows the influence of population density, industrial processes and agricultural activities on TSP concentrations. The lowest concentrations are at the Moose City, Polebridge, Columbia Falls - NAAC, Ninepipe and Swan River Youth Camp sites, while the highest levels are at the Columbia Falls-Anders and Kalispell-Universal Athletic sites. Annual average concentrations for the later two sites were above the Montana standard of 75 micrograms per cubic meter in 1980, 1981, and 1982.

Tables 2-A through 2-0 show monthly trends in TSP levels at the TSP monitoring sites. These levels are graphically presented for the Universal Athletics and Anders Residence sites in Figures 2-A and 2-B.

The second device used for measuring particulates in the Flathead Study was the dichotomous sampler. This sampler also employs a filter media much as the high volume sampler does, but collection is limited to a much smaller size range. Two filters are used, one collects particles less than 2.5 microns in size and the other collects particles between 2.5 microns and 15 microns. Particles larger than 15 microns are not collected by the dichotomous sampler so its results cannot be compared directly with high volume air sampler results.

Three sites in the Basin were equipped with dichotomous samplers in 1978 and 1979. These were Polebridge, Kalispell-Airport, and Polson. During 1980 two more dichotomous samplers were installed at the Columbia Falls-Anders and Kalispell-Universal Athletics sites. A sixth dichotomous sampler was installed at the Ninepipe site in 1981. Due to inherent design problems that the AQB was unaware of, data recovery from the dichotomous samplers was less than desired. The data presented in Tables 3-A through 3-F represent data which was reviewed in detail to eliminate questionable values.

In general, concentrations of fine particles (less than 2.5 microns in size) do not vary as much from site to site as the concentrations of TSP and coarse particulate (between 2.5 and 15 microns in size). This reflects the longer residence times of very small suspended particles which allows them to spread throughout the Basin instead of falling out close to the source.

A site by site comparison of particulate sampling sites and results follows.

1. Moose City - site 480_034.

The Moose City site was located 12 meters west of the North Fork road and 4 meters south of the U.S.-Canadian border. The high volume sampler was located on a platform at a height of 3 meters. The surrounding terrain was very rugged, with mountains rising to the west and just across the river to the east. The site was very remote and essentially undeveloped. There was little or no traffic on the gravel road near the site during the monitoring period, as the border crossing is only open during the summer. The effective sampling range was regional in scope. The sampler was operated from September 1978 to March of 1979. Sample success was very poor (about 50 percent) as the only power for this site was provided by portable generators. The generators used were not adequate for the power demand and continued failures forced an early termination

of monitoring at this site. TSP levels were very low for the sampling period with an overall average of 13 micrograms per cubic meter and a maximum reading of 40 micrograms per cubic meter.

2. Polebridge - site 480_035.

The Polebridge site is located just east of the North Fork of the Flathead River at the Polebridge Ranger Station in Glacier National Park. The sampling platform is on the south end of the roof of a large storage shed and garage at a height of 8 meters. The surrounding terrain is very rugged, with mountains rising abruptly on either side of the valley. The site is about one kilometer northeast of the small community of Polebridge which is located on the other side of the river. There are very few year round residents in the area but during the summer, seasonal residents and tourists generate a light but steady flow of traffic up and down the North Fork road and into Glacier National Park. None of the roads in the area are paved and significant amounts of fugitive dust are generated by the traffic on dry days. The road near the sampler includes a stop for vehicles entering Glacier National Park, which keeps vehicle speeds low in the immediate vicinity of the sampler. The sampler is high enough that the readings are not disproportionately impacted by large particles from nearby traffic. The effective sampling range of this site is considered to be regional.

A dichotomous sampler was operated at this site from September 1978 to May 1981. A high volume air sampler has been sampling there since 1981. Power for the site is provided by a generator located on the opposite end of the building from the sampler. The generator exhaust is about six meters below the sampler and ten meters north.

TSP levels measured here exhibit drastic seasonal changes, with much higher readings during the summer. July and August levels average about 45 micrograms per cubic meter, while the months from November to March average only about ten micrograms per cubic meter. The annual average for 1982 was 19 micrograms per cubic meter. The data from the dichotomous sampler indicated that most of the seasonal variation in TSP resulted from larger particles. Fine particulate levels did not quite double from winter to summer, while levels in the 2.5 to 15 micron range went up by a factor of about five. The higher summer particulate levels are probably traffic generated. The highest fine particles levels were measured during the fall slash burning season.

3. Columbia Falls - NAAC - site 480 029.

The NAAC site was located one kilometer northwest of the Anaconda Aluminum plant on a small hill. The sampler was mounted on a platform 2.5 meters above ground level. The surrounding terrain was very rugged and the vegetative cover near the sampler was undisturbed. The effective sampling range was regional.

The NAAC high volume air sampler was operated from January 1978 through December 1982. This sampler represented background TSP levels in the Columbia Falls area. The levels were only moderately seasonal with summer and fall values not quite twice the winter levels. The average TSP level for the entire sampling period was 26 micrograms per cubic meter.

4. Columbia Falls - Anders site 270 005.

The Anders site is located one block east of Nucleus Avenue on a garage behind the Roy Anders residence in Columbia Falls. The dichotomous sampler and the high volume sampler were mounted on a platform at a height of five meters. This site is located in a residential neighborhood with lightly traveled, unpaved roads. Nucleus Avenue to the west has very heavy traffic and is above the sampler site. There are numerous wood stove stacks in the immediate

vicinity. These nearby sources limit the effective range of this site to a neighborhood scale or less.

The high volume sampler has been operated since January 1978. The dichotomous sampler ran successfully from January through October 1980. This site has always recorded very high levels of TSP with an overall average of 128 micrograms per cubic meter over the last five years. As a result of these high levels, Columbia Falls has been designated as a non-attainment area for TSP. TSP levels are seasonal, with summer readings about three times higher than those in the winter. The dichotomous sampler results show a peak in the fine (less than 2.5 microns) particle levels during the winter and a peak in the 2.5 to 15 micron particles during the summer. The winter peak for particles less than 2.5 microns is most likely the result of residential wood burning. The summer peak of larger particles is clearly a result of fugitive dust.

During the summer of 1982 the TSP levels at this site dropped significantly. This coincided with the completion of a repaving project on Nucleus Avenue just west of the site. This should result in a permanent reduction of TSP levels, but the size of the reduction will not be clearly defined without future monitoring.

5. Whitefish - site_480_037_

The Whitefish site was located just over the right field fence at the Memorial Park baseball complex. The site was close to the eastern edge of the city in a residential neighborhood. The streets in the vicinity were all paved and all of the open areas were covered with grass. During the winter months the ground was usually covered with more than a foot of snow. The effective sampling range of this site was neighborhood.

The high volume air sampler operated on a platform at a height of three meters from August 1981 through June 1983. The average TSP level for this site

was 61 micrograms per cubic meter. The TSP levels were not seasonal, with high winter levels due to wood smoke balancing the effect of summer fugitive dust.

6. Kalispell GIA - site 480_304.

The GIA site was located east of the private hangars at the Glacier International Airport and west of LaSalle Road, 13 kilometers north northeast of Kalispell. Prior to October of 1980 the site was located 200 yards south of this site. A high volume air sampler and a dichotomous sampler were situated on top of a trailer at a height of four meters. Aside from the airport and LaSalle Road, the surrounding area was predominately rural agricultural in nature. The vegetative cover around the site was primarily grass, with a few trees in the distance. The effective sampling range of the site was regional.

The high volume sampler and the dichotomous sampler operated at this site from March of 1979 and September of 1978 respectively. This site was representative of background concentrations in the rural-agricultural areas of the Flathead Valley north of Flathead Lake. The four year average TSP concentration for this site was 47 micrograms per cubic meter. The TSP levels were moderately seasonal, with late summer and early fall concentrations about twice as high as the winter levels. This pattern was duplicated by the dichotomous sampler readings for particles between 2.5 and 15 microns. The concentrations for fine particles less than 2.5 microns did not show any strong seasonal trend except for occasional peaks possibly due to wood smoke during the fall slash burning season.

7. Kalispell-Strom - site 800_014.

The Strom site was located next to the alley between 4th and 5th Avenue East in Kalispell. The high volume air sampler was located on a garage at a height of four meters. The sampler was in a residential neighborhood consisting mainly of older two story houses. There were many large trees in all directions. The

alley was unpaved but traffic was very light. All other streets in the vicinity were paved. The site was obstructed by the trees and did not meet siting criteria, so it was discontinued.

The high volume sampler operated from October 1978 through December of 1979. The average TSP concentration was 87 micrograms per cubic meter.

8. Kalispell - Universal Athletics - site 800 015.

The Universal Athletic Site is located atop a one story building overlooking an alley one half block west of Main Street. The high volume air sampler and a dichotomous sampler were installed at a height of five meters. The surrounding area is urban commercial with several paved parking lots nearby. The majority of the surrounding buildings are one and two story commercial establishments. The effective sampling range of this site is neighborhood.

The dichotomous sampler operated successfully in 1980 and the high volume air sampler has been in operation continuously since its installation in January of 1980. The three year average TSP level for this site was 93 micrograms per cubic meter, with no apparent seasonal trends. The dichotomous sampler readings showed a strong increase in fine particles levels (less than 2.5 microns) during the winter months due to residential wood smoke. This balanced low fugitive dust emission occurring during the summer and kept the TSP levels high throughout the year.

9. Kalispell Evergreen - site 800 016.

The Evergreen site was located in the equipment yard behind the Flathead Rural Electric Cooperative building about five kilometers north northeast of Kalispell and just west of LaSalle Road. The high volume air sampler was located on a platform at a height of three meters. The surrounding neighborhood

was a rural-suburban-commercial-industrial mix, with houses and mobile home parks interspersed with small agricultural fields, a plywood mill to the southwest and retail establishments along the highway. Many of the residences in the area have wood stoves and the plywood plant burns wood wastes for process steam. Most of the roads near the sampler site were paved but the sampler was located in a gravel surfaced storage area. However, traffic on the unpaved portion of the equipment yard was slow and infrequent and should not have significantly impacted the measured TSP levels. The effective sampling range of this site was neighborhood in scale.

The high volume sampler operated from June 1980 through December 1982. The overall average TSP level measured at this site during the two and one half years it operated was 62 micrograms per cubic meter. TSP levels were moderately seasonal with summer readings about two and one half times the winter concentrations.

10. Bigfork - site 480 036.

The Bigfork site was located at the Bigfork District Ranger Station on a hill just northwest of Bigfork. The high volume air sampler was located on a platform at a height of two and one half meters above ground. The surrounding terrain consisted of rolling hills to the north and east, the north end of the Mission Mountain Range to the southeast and Flathead Lake to the south and west. The area to the east and southeast was residential-commercial in nature while to the north agricultural fields and forest lands were predominate.

The high volume sampler operated from July of 1979 through December of 1982. The average TSP level for the three and one half years was 37 micrograms per cubic meter. There were no consistent seasonal trends in TSP observed at this site.

11. Polson - site 820 010.

The Polson site was located three and one half kilometers east of Polson, one and one half kilometers south of Flathead Lake, and just north of Montana Highway 35. A dichotomous sampler and a high volume air sampler operated on a platform at a height of three meters. The surrounding terrain was level with gentle hills rising to the south and west about one kilometer away. The Mission Mountains rise seven kilometers to the east. The site was in a commercial-rural-industrial area, with a lumber mill to the southwest, gravel pits to the south, commercial establishments along the highway, and fields and orchards to the north, east and south. The effective sampling range was neighborhood.

The dichotomous sampler ran from September 1978 through August 1980 and the high volume air sampler operated from March 1979 through June 1983. TSP levels in 1979 were approximately twice those observed during 1981 and 1982. The high readings during 1979 may have been caused by a nearby highway construction project or the fact that the site was located 200 yards south of the more recent location at that time. The average TSP concentration for 1981 and 1982 was 43 micrograms per cubic meter. TSP levels were higher in the early spring and again during the summer and early fall. The dichotomous sampler results showed a similar pattern for coarse particles (2.5 and 15 microns) but no clear pattern for particles less than 2.5 microns was observed. These measurements strongly suggest that fugitive dust was the main contributor to TSP levels at this site.

12. Ronan -site 820 011.

The Ronan site was located one and one half kilometers south of Ronan just east of Highway 93. The high volume air sampler was located on a platform at a height of three meters. The surrounding area was low density commercial with many vacant areas on both sides of the highway. A gravel road ran only 30

meters south of the sampler. The site was discontinued because emissions from the road were believed to be significantly biasing the data from this site.

The sampler operated from November 1978 through July of 1980. The average TSP level for the sampling period was 97 micrograms per cubic meters.

13. Ninepipe - site 820 012.

The Ninepipe site was located just north of Ninepipe Reservoir about 200 meters north of Montana Highway 212. A high volume sampler and a dichotomous sampler operated on platforms at a height of three meters. The surrounding terrain was level and there were no disturbed areas or unpaved roads nearby. The site was quite remote, with no nearby residences or other human activity. The effective sampling range of this site was regional.

The high volume air sampler ran from October 1979 through June 1983. The dichotomous sampler data is for 1981 only. This site was representative of background TSP levels in the Flathead Basin south of Flathead Lake. The average TSP concentration measured over the two and one half years was 21 micrograms per cubic meter. TSP levels were quite seasonal, with summer concentrations averaging three times higher than winter levels. The dichotomous sampler results for fine particles (less than 2.5 microns) did not exhibit the same pattern as for TSP, but measurements of particles between 2.5 and 15 microns did. This probably reflects the preponderance of fugitive emissions impacting the site.

14. Swan River Youth Camp - site 820 017.

The Swan River Youth Camp site was located west of the Administration Building at the Swan River Youth Forest Camp in the Seeley-Swan Valley about 18 kilometers south of Swan Lake. The site was located close to the middle of the valley bottom which is about 8 kilometers wide at this point. The Mission Mountains to the west and the Swan Range to the east bound the valley.

The youth camp complex is typical of the population centers in the Seeley-Swan Valley, which tend to be small clusters of dwellings near the highway. The roads in the area were not paved and during the summer were quite dusty. During the winter, however, the valley was usually covered with several feet of snow and the only appreciable emissions were wood smoke from residential heating.

The high volume air sampler operated during 1982. The winter snow cover caused highly seasonal TSP levels with very low winter levels (5-10 micrograms per cubic meter) and moderately high summer concentrations. Unfortunately, a new building was constructed at the youth camp in the summer of 1982 and heavy traffic on a temporary dirt road right next to the sampler severely biased the July, August and September measurements. An analysis of weekend data indicated that the July, August and September TSP levels should more typically average about 70 micrograms per cubic meter or about 10 times the winter levels. The measured annual TSP concentration here was 29 micrograms per cubic meter. A more representative average (throwing out samples obviously impacted by construction traffic) would be 24 micrograms per cubic meter, or about the same as the Polebridge and Ninepipe levels.

C. Sulfates and Nitrates

Sulfate and nitrate analyses were performed on the filters from the high volume samplers from all sites except Kalispell-Evergreen. Monthly arithmetic means and maximums of sulfate and nitrate concentrations are presented in Tables 2-A through 2-0 along with the TSP values. The values were generally highest in the more urban or industrialized areas and lowest in the rural areas. The highest value (12.8 micrograms/cubic meter) was recorded at the Columbia Falls-NAAC site in February 1978. This site exhibited sulfate values similar to those at the Columbia Falls-Anders site even though the TSP levels were only about one fifth as high. This was probably due to the nearby aluminum plant.

1981 and 1982 sulfate levels at the Polebridge site were second only to the Kalispell-Universal Athletics site and were unusually high for such a remote site. These high levels may be caused by emissions from the gas fields 50 miles northeast of the site in Alberta or by the exhaust of the generator located at the site or by sulfates contained in the fugitive dust off of nearby roads and soil.

The nitrate levels were uniformly lower than the sulfate levels but exhibited much the same pattern. The highest nitrate level recorded was 10.9 micrograms per cubic meter in February, 1980 at the Kalispell-Universal Athletics site. The lowest nitrate value recorded was 0.0 micrograms per cubic meter at the Polebridge site.

D. Visibility

Montana has a visibility standard for PSD Class I areas based on integrating nephelometer measurements. The nephelometer measures a dimensionless scattering coefficient over a one meter light path using an artificial light source. The Montana standard requires an annual mean value no more than 3.0×10^{-5} for Class I areas. Although the Flathead Basin contains several Class I areas (Glacier National Park, Bob Marshall Wilderness, and Mission Mountain Wilderness), no nephelometer measurements were taken in those areas due to logistical considerations. Visibility measurements were taken at two locations in the study area: Glacier International Airport (GIA) north of Kalispell, and Ninepipe Wildlife Refuge south of Ronan. The nephelometer at GIA operated from 1978 through June of 1983. Data for this site is listed in Table 4-A. A second nephelometer operated at the Ninepipe site from July 1981 until July of 1983. Data from this site is presented in Table 4-B.

Visibility at the Ninepipe site was noticeably better than that at GIA, particularly during the late fall and winter when wood smoke traditionally is a problem.

FLATHEAD RIVER BASIN ENVIRONMENTAL IMPACT STUDY STUDY AREA MAP

MONITOR SITES:

- 1) MOOSE CITY
- 2) POLEBRIDGE
- 3) COL. FALLS - NAAC
- 4) COL. FALLS - ANDERS
- 5) KALISPELL - AIRPORT
- 6) KALISPELL - STROM
- 7) KALISPELL - UNIV. ATM.
- 8) KALISPELL - EVERGREEN
- 9) BIG FORK
- 10) POLBON
- 11) RONAN
- 12) NINE PIPE
- 13) WHITEFISH
- 14) SWAN YOUTH CAMP
- 15) RONAN (TRIBAL)
- 16) ST. IGNATIUS (TRIBAL)
- 17) ARLEE
- 18) EVARO

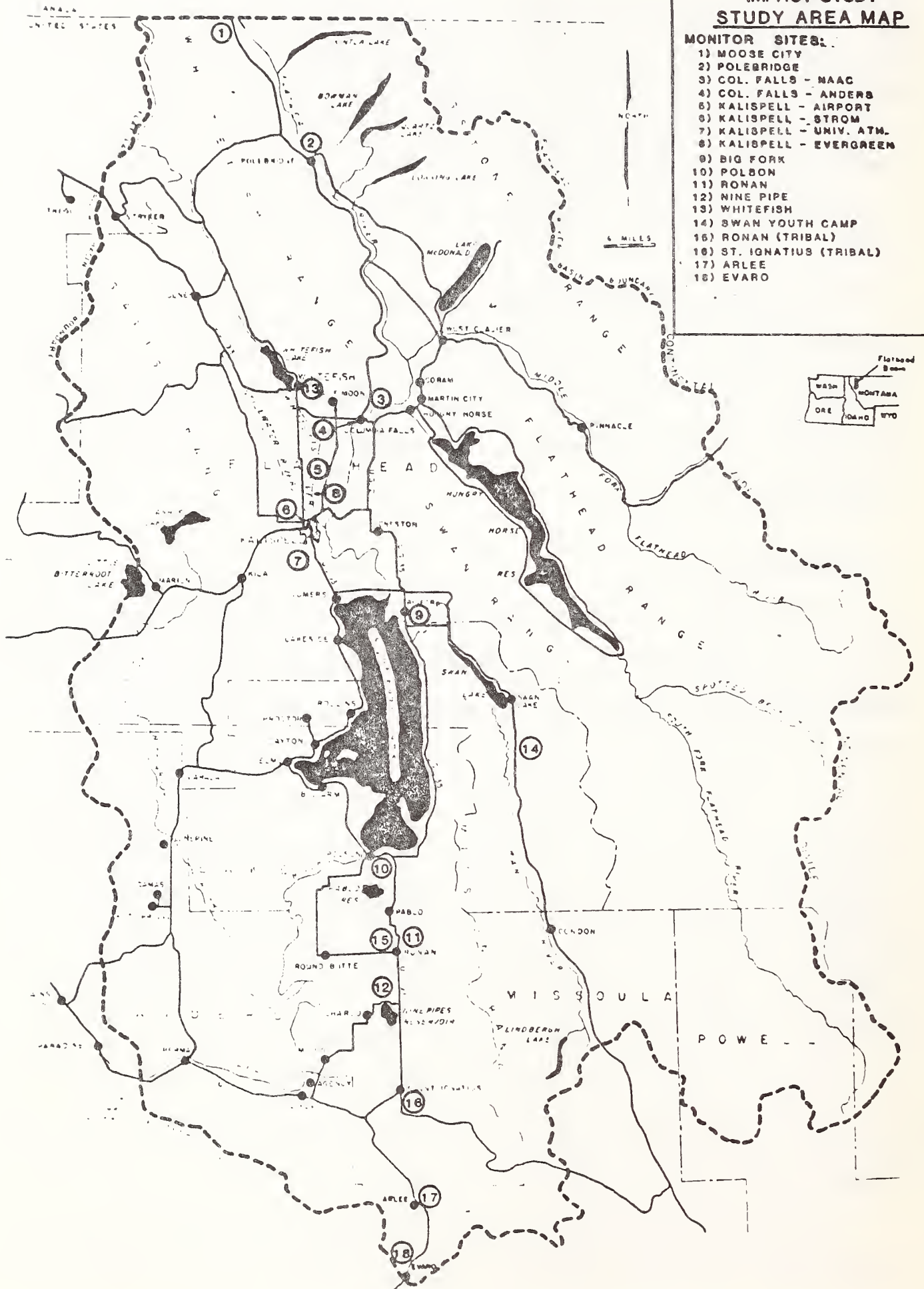
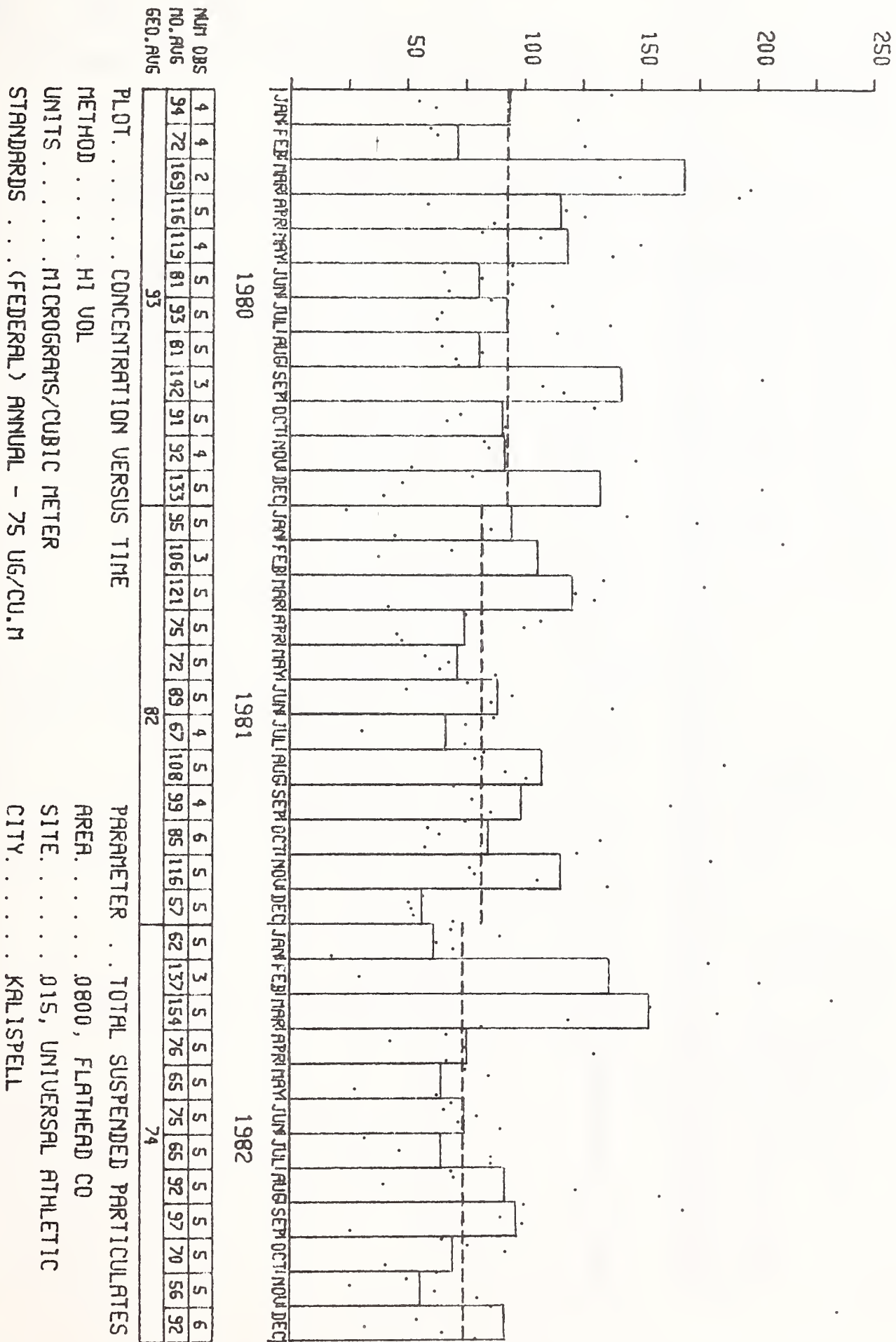


Figure 1-A
20

Figure 2-A



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22

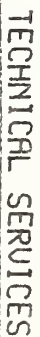


TABLE 1-A

Flathead Basin TSP Levels
 Maximums, (Second High Reading), and [Arithmetic Average]*
 1978 through 1982

Site	1978 Max(2nd)[Ave]	1979 Max(2nd)[Ave]	1980 Max(2nd)[Ave]	1981 Max(2nd)[Ave]	1982 Max(2nd)[Ave]
Moose City	40 (18)[15]	15 (12)[10]			
Polebridge				89 (62)[30]	89(60)[19]
Columbia Falls NAAC	59 (56)[25]	64 (63)[29]	106 (81)[30]	89 (83)[30]	49(45)[18]
Columbia Falls- Anders	425 (423)[134]	484 (390)[145]	498 (455)[129]	494 (390)[148]	241(225)[85]
Whitefish				144 (128)[73]	138(130)[56]
Kalispell- GIA		140 (120)[56]	309 (232)[62]	134 (103)[39]	94(89)[31]
Kalispell- Strom	110 (105)[65]	343 (289)[90]			
Kalispell- Universal Athletic			296 (202)[103]	211 (186)[90]	234(232)[85]
Kalispell- Evergreen			169 (138)[67]	170 (159)[65]	176(176)[54]
Bigfork		112 (103)[43]	134 (102)[42]	109 (84)[32]	80(78)[29]
Polson		202 (191)[80]	177 (159)[62]	174 (111)[44]	100(95)[42]
Ronan	170 (120)[48]	405 (311)[109]	220 (175)[88]		
Ninepipes			42 (35)[21]	142 (55)[24]	71(54)[18]
Ronan (Tribal)					272(206)[74]
St. Ignatius (Tribal)					187(172)[71]
Arlee (Tribal)					772(77)[48]
Evano (Tribal)					114(84)[33]
Swan Youth Camp					306(236)[29]

*All values in micrograms per cubic meter

TABLE 2-A

Moose City
 Particulate Data*
 Total Suspended Particulates, TSP
 Sulfates (SO₄) and Nitrates [NO₃]

Month	Arithmetic Mean			Maximum Reading		
	TSP	(SO ₄)	[NO ₃]	TSP	(SO ₄)	[NO ₃]
Sept. 78	18	(1.6)	[0.4]	18	(2.4)	[0.6]
Oct.	26	(1.6)	[0.2]	40	(1.9)	[0.2]
Nov	--	--	--	--	--	--
Dec	9	(4.5)	[0.3]	17	(6.1)	[0.4]
Jan 79	--	--	--	--	--	--
Feb	10	(2.9)	[0.2]	12	(4.2)	[0.3]
Mar	10	(2.6)	[0.3]	15	(4.0)	[0.4]

*All values in micrograms per cubic meter

TABLE 2-B

Polebridge
Particulate Data*
Total Suspended Particulates, TSP
Sulfates (SO₄) and Nitrates [NO₃]
May 1981 - December 1982

Month	Arithmetic Mean			Maximum Reading		
	TSP	(SO ₄)	[NO ₃]	TSP	(SO ₄)	[NO ₃]
May 81	24	(4.5)	[0.1]	24	(4.5)	[0.1]
June	28	(3.5)	[0.0]	47	(4.3)	[0.1]
July	43	(3.5)	[0.1]	62	(3.7)	[0.2]
Aug	57	(3.2)	[0.2]	89	(4.9)	[0.3]
Sep	25	(3.0)	[0.1]	33	(4.3)	[0.3]
Oct	21	(4.1)	[0.3]	29	(4.9)	[0.4]
Nov	17	(2.3)	[0.1]	30	(3.1)	[0.3]
Dec	10	(1.0)	[0.0]	10	(1.0)	[0.0]
Jan 82	9	(3.6)	[0.3]	14	(6.5)	[0.5]
Feb	10	(2.5)	[0.1]	16	(3.5)	[0.3]
Mar	6	(2.1)	[0.1]	11	(3.6)	[0.2]
Apr	15	(2.8)	[0.2]	26	(4.0)	[0.4]
May	20	(4.3)	[0.2]	25	(5.3)	[0.5]
Jun	28	(4.2)	[0.3]	38	(5.7)	[0.5]
Jul	43	(3.2)	[0.2]	89	(5.4)	[0.4]
Aug	16	(3.3)	[0.3]	19	(3.7)	[0.3]
Sep	23	(3.3)	[0.2]	33	(3.4)	[0.3]
Oct	13	(1.3)	[0.3]	18	(2.3)	[0.3]
Nov	9	(1.5)	[0.3]	9	(1.5)	[0.3]
Dec	8	(2.9)	[0.1]	8	(2.9)	[0.1]

*All values in micrograms per cubic meter

TABLE 2-C (1)

Columbia Falls - NAAC
 Particulate Data *
 Total Suspended Particulates, TSP
 Sulfates (SO₄) and Nitrates [NO₃]
 January 1978 - January 1979

Month	Arithmetic Mean			Maximum Reading		
	TSP	(SO ₄)	[NO ₃]	TSP	(SO ₄)	[NO ₃]
Jan 78	23	(4.5)	[2.0]	55	(9.6)	[5.6]
Feb	24	(6.2)	[1.1]	47	(12.8)	[2.4]
March	33	(3.1)	[1.6]	42	(6.4)	[2.3]
April	13	(2.4)	[0.4]	21	(3.4)	[0.6]
May	26	(2.6)	[0.5]	46	(4.5)	[1.0]
June	21	(2.3)	[0.3]	33	(3.3)	[0.5]
July	28	(2.7)	[0.5]	48	(4.1)	[0.8]
Aug	29	(3.4)	[0.5]	37	(5.2)	[0.6]
Sep	26	(2.9)	[0.6]	30	(4.6)	[0.9]
Oct	39	(2.8)	[0.6]	59	(5.0)	[1.0]
Nov	24	(3.7)	[1.3]	53	(9.1)	[3.2]
Dec	8	(1.9)	[0.7]	16	(3.5)	[1.8]
Jan 79	32	(5.0)	[1.8]	48	(7.1)	[2.9]

TABLE 2-C (2)

Columbia Falls - NAAC
 Particulate Data*
 Total Suspended Particulate (TSP)
 January 1979 - December 1982

Month	1979		1980		1981		1982	
	Mean	(Max)	Mean	(Max)	Mean	(Max)	Mean	(Max)
Jan	32	(48)	24	(35)	34	(57)	19	(32)
Feb	27	(50)	20	(43)	18	(33)	19	(49)
Mar	21	(37)	17	(21)	15	(27)	10	(14)
Apr	22	(63)	18	(28)	20	(40)	21	(43)
May	28	(94)	24	(45)	19	(25)	24	(40)
Jun	29	(35)	31	(53)	28	(51)	22	(30)
Jul	30	(42)	41	(81)	49	(89)	22	(31)
Aug	32	(57)	31	(53)	49	(79)	22	(37)
Sep	33	(43)	44	(65)	47	(83)	22	(45)
Oct	33	(49)	56	(106)	30	(39)	19	(28)
Nov	34	(60)	22	(56)	36	(54)	7	(11)
Dec	31	(64)	23	(38)	24	(37)	12	(30)

*All values in micrograms per cubic meter

TABLE 2-D (1)

Columbia Falls - Anders
Particulate Data*
Total Suspended Particulates (TSP)
Sulfates (SO₄) and Nitrates [NO₃]
January 1978 - January 1979

Month	Arithmetic Mean			Maximum Reading		
	TSP	(SO ₄)	[NO ₃]	TSP	(SO ₄)	[NO ₃]
Jan 78	47	(5.1)	[2.3]	78	(9.2)	[5.6]
Feb	80	(5.3)	[1.5]	209	(9.9)	[4.0]
March	292	(3.3)	[1.7]	426	(5.1)	[2.2]
April	137	(2.9)	[0.5]	328	(3.9)	[1.0]
May	157	(2.9)	[0.6]	208	(3.8)	[1.1]
June	117	(2.8)	[0.5]	208	(5.0)	[0.8]
July	154	(3.4)	[0.6]	311	(4.8)	[0.9]
Aug	177	(4.0)	[0.7]	375	(5.2)	[1.4]
Sep	137	(2.9)	[0.8]	186	(4.7)	[1.2]
Oct	165	(3.1)	[1.0]	249	(4.8)	[1.5]
Nov	102	(5.7)	[2.8]	152	(8.2)	[5.1]
Dec	35	(3.1)	[1.6]	58	(4.4)	[4.1]
Jan 79	40	(6.1)	[2.7]	113	(8.3)	[3.7]

*All values in micrograms per cubic meter

TABLE 2-D (2)

Columbia Falls - Anders
Particulate Data*
Total Suspended Particulate (TSP)
January 1979 - December 1982

Month	1979		1980		1981		1982	
	Mean	(Max)	Mean	(Max)	Mean	(Max)	Mean	(Max)
Jan	40	(113)	83	(188)	91	(197)	45	(78)
Feb	51	(79)	48	(81)	146	(222)	88	(177)
Mar	169	(353)	108	(140)	157	(369)	91	(177)
Apr	174	(257)	139	(225)	150	(390)	119	(241)
May	205	(375)	73	(122)	122	(308)	98	(168)
Jun	186	(26)	82	(125)	108	(252)	68	(127)
Jul	161	(254)	189	(455)	319	(404)	119	(184)
Aug	119	(210)	131	(206)	167	(231)	101	(186)
Sep	240	(279)	175	(267)	179	(292)	138	(225)
Oct	207	(484)	241	(422)	144	(312)	69	(118)
Nov	112	(212)	104	(235)	113	(242)	44	(90)
Dec	49	(84)	159	(498)	74	(135)	57	(101)

*All values in micrograms per cubic meter

TABLE 2-E

Whitefish
 Particulate Data*
 Total Suspended Particulates, TSP
 Sulfates (SO₄) and Nitrates [NO₃]
 August 1981 - December 1982

Month	Arithmetic Mean			Maximum Reading		
	TSP	(SO ₄)	[NO ₃]	TSP	(SO ₄)	[NO ₃]
Aug 81	74	(3.0)	[0.9]	105	(3.3)	[1.3]
Sep	65	(2.8)	[0.7]	96	(4.7)	[0.9]
Oct	81	(3.2)	[1.1]	106	(4.3)	[1.3]
Nov	83	(1.7)	[1.3]	144	(3.0)	[2.0]
Dec	62	(1.6)	[1.2]	84	(2.8)	[1.6]
Jan 82	52	(3.7)	[1.6]	63	(5.9)	[2.4]
Feb	72	(2.2)	[1.5]	130	(5.4)	[3.0]
Mar	72	(0.9)	[0.6]	86	(1.4)	[1.0]
Apr	74	(1.5)	[0.5]	138	(2.0)	[0.6]
May	71	(1.9)	[0.6]	99	(3.6)	[1.1]
Jun	48	(2.1)	[0.7]	86	(2.9)	[0.9]
Jul	45	(1.7)	[0.6]	72	(2.9)	[0.8]
Aug	43	(2.1)	[0.7]	75	(2.6)	[0.9]
Sep	47	(1.9)	[0.5]	77	(2.6)	[0.8]
Oct	72	(0.7)	[1.0]	119	(1.1)	[1.4]
Nov	35	(2.0)	[1.1]	46	(6.2)	[1.7]
Dec	45	(1.6)	[1.5]	74	(2.5)	[2.0]

*All values in micrograms per cubic meter

TABLE 2-F

Glacier International Airport
Particulate Data*
Total Suspended Particulates TSP
Sulfates (SO₄) and Nitrates [NO₃]
March 1979 - December 1982

Month	Arithmetic Mean			Maximum Reading		
	TSP	(SO ₄)	[NO ₃]	TSP	(SO ₄)	[NO ₃]
Mar 79	79	(3.2)	[2.8]	120	(4.5)	[5.6]
April	50	(2.3)	[1.1]	117	(4.0)	[1.6]
May	53	(2.2)	[0.9]	74	(3.3)	[1.1]
June	54	(2.0)	[0.9]	69	(2.2)	[1.3]
July	67	(2.3)	[0.8]	89	(2.9)	[1.0]
Aug	61	(2.5)	[0.8]	109	(2.9)	[1.6]
Sep	73	(2.5)	[1.0]	107	(3.2)	[1.2]
Oct	73	(3.1)	[1.5]	140	(3.8)	[1.8]
Nov	38	(3.8)	[2.1]	57	(5.0)	[3.6]
Dec	25	(2.4)	[1.6]	34	(2.9)	[3.0]
Jan 80	36	(3.9)	[2.2]	45	(5.3)	[2.9]
Feb	38	(3.5)	[3.1]	67	(6.4)	[4.0]
Mar	23	(2.2)	[0.9]	33	(3.5)	[1.6]
April	50	(3.2)	[0.6]	88	(4.5)	[1.0]
May	41	(2.5)	[0.4]	46	(3.8)	[0.6]
June	86	(3.0)	[0.6]	232	(4.9)	[0.8]
July	74	(3.5)	[0.3]	138	(4.8)	[0.7]
Aug	89	(3.8)	[0.3]	230	(4.8)	[0.6]
Sep	90	(4.0)	[0.5]	142	(6.2)	[0.8]
Oct	112	(4.1)	[1.3]	309	(4.8)	[1.8]
Nov	40	(3.0)	[1.2]	78	(4.1)	[2.5]
Dec	34	(4.7)	[1.2]	45	(7.7)	[1.8]
Jan 81	35	(3.8)	[1.9]	51	(5.9)	[3.1]
Feb	30	(3.5)	[0.8]	42	(6.6)	[1.5]
Mar	25	(1.8)	[0.9]	53	(3.7)	[2.0]
April	25	(2.0)	[0.6]	38	(2.3)	[0.9]
May	28	(2.5)	[0.4]	65	(3.6)	[0.6]
June	29	(1.8)	[0.3]	60	(2.5)	[0.6]
July	52	(2.1)	[0.5]	84	(2.5)	[0.7]
Aug	75	(3.3)	[1.0]	134	(3.5)	[1.6]
Sep	60	(2.4)	[0.8]	103	(3.2)	[1.2]
Oct	44	(3.2)	[1.1]	71	(5.1)	[1.4]
Nov	39	(1.0)	[1.3]	91	(2.3)	[2.1]
Dec	26	(2.3)	[1.8]	51	(5.5)	[3.0]
Jan 82	27	(4.0)	[1.9]	98	(10.7)	[3.2]
Feb	26	(2.7)	[1.8]	45	(6.6)	[3.9]
Mar	19	(1.9)	[0.3]	25	(6.0)	[0.8]
Apr	30	(0.6)	[0.3]	62	(1.0)	[0.8]
May	29	(1.6)	[0.4]	51	(3.4)	[1.2]
Jun	31	(2.3)	[0.8]	41	(2.6)	[1.0]
Jul	39	(2.0)	[0.7]	86	(3.7)	[1.0]
Aug	43	(2.3)	[0.7]	80	(3.1)	[1.0]
Sep	56	(2.5)	[0.6]	94	(3.2)	[0.9]
Oct	38	(1.4)	[0.8]	73	(1.9)	[1.3]
Nov	14	(2.1)	[0.6]	19	(4.8)	[0.9]
Dec	23	(1.7)	[1.2]	39	(3.0)	[2.0]

*All values in micrograms per cubic meter

TABLE 2-G

Kalispell - Strom
 Particulate Data*
 Total Suspended Particulates, TSP
 Sulfates (SO₄) and Nitrates [NO₃]
 October 1978 - December 1979

Month	Arithmetic Mean			Maximum Reading		
	TSP	(SO ₄)	[NO ₃]	TSP	(SO ₄)	[NO ₃]
Oct 78	85	(3.5)	[1.0]	110	(3.9)	[1.2]
Nov	67	(5.8)	[2.5]	99	(8.2)	[4.8]
Dec	43	(4.6)	[1.6]	63	(5.0)	[3.2]
Jan 79	41	(7.6)	[3.0]	59	(8.5)	[4.1]
Feb	58	(5.3)	[3.9]	59	(6.4)	[6.6]
March	164	(4.8)	[2.7]	343	(7.0)	[4.0]
April	147	(4.6)	[1.5]	184	(4.9)	[1.8]
May	107	(2.4)	[1.0]	135	(2.8)	[1.3]
June	63	(2.4)	[0.9]	76	(2.8)	[1.0]
July	95	(2.7)	[0.7]	140	(3.0)	[1.1]
Aug	73	(2.9)	[0.7]	156	(3.6)	[1.3]
Sep	126	(3.7)	[1.2]	208	(6.3)	[2.3]
Oct	--	--	--	--	--	--
Nov	87	(6.0)	[2.9]	136	(9.1)	[5.4]
Dec	67	(3.0)	[1.8]	110	(3.6)	[2.9]

*All values in micrograms per cubic meter

TABLE 2-H
 Kalispell - Universal Athletics
 Particulate Data*
 Total Suspended Particulates, TSP
 Sulfates (SO₄) and Nitrates [NO₃]
 January 1980 - December 1982

Month	Arithmetic Mean			Maximum Reading		
	TSP	(SO ₄)	[NO ₃]	TSP	(SO ₄)	[NO ₃]
Jan 80	92	(5.3)	[2.0]	137	(6.4)	[2.5]
Feb	72	(4.8)	[5.7]	126	(6.4)	[10.9]
March	169	(4.4)	[1.3]	197	(5.7)	[2.5]
April	116	(4.0)	[0.4]	192	(5.1)	[0.8]
May	119	(4.0)	[0.5]	150	(5.2)	[0.6]
June	81	(2.5)	[0.5]	95	(2.8)	[0.6]
July	93	(3.2)	[0.6]	137	(4.8)	[0.9]
Aug	81	(4.9)	[0.1]	114	(6.5)	[0.5]
Sep	142	(5.7)	[1.2]	202	(7.1)	[1.7]
Oct	91	(4.0)	[1.3]	130	(5.6)	[1.8]
Nov	92	(5.9)	[1.5]	148	(8.8)	[2.4]
Dec	133	(5.5)	[1.3]	296	(6.1)	[2.0]
Jan 81	95	(5.8)	[1.9]	174	(8.0)	[3.7]
Feb	106	(6.1)	[0.7]	211	(7.9)	[0.8]
Mar	121	(3.5)	[1.1]	177	(4.2)	[1.5]
Apr	75	(3.9)	[0.7]	107	(4.5)	[1.2]
May	72	(4.0)	[0.6]	88	(5.1)	[0.8]
June	89	(4.6)	[0.5]	138	(5.3)	[0.6]
July	67	(3.0)	[0.6]	87	(3.4)	[0.7]
Aug	108	(4.2)	[1.0]	86	(4.8)	[1.3]
Sep	99	(4.1)	[1.0]	163	(5.8)	[1.2]
Oct	85	(5.2)	[1.3]	133	(6.5)	[2.1]
Nov	116	(2.9)	[1.8]	180	(3.7)	[3.8]
Dec	57	(3.5)	[2.2]	70	(4.4)	[3.1]
Jan 82	62	(5.3)	[2.0]	90	(7.9)	[3.0]
Feb	137	(4.9)	[1.6]	201	(9.0)	[2.9]
Mar	154	(3.2)	[0.4]	232	(5.5)	[1.2]
Apr	76	(2.6)	[0.5]	130	(5.5)	[0.8]
May	65	(2.3)	[0.5]	85	(2.8)	[1.1]
Jun	75	(3.2)	[0.8]	90	(3.8)	[1.0]
Jul	65	(2.1)	[0.7]	86	(3.3)	[1.0]
Aug	92	(3.5)	[0.8]	158	(4.3)	[1.0]
Sep	97	(3.2)	[0.6]	168	(3.8)	[0.9]
Oct	70	(1.8)	[1.1]	92	(3.3)	[1.5]
Nov	56	(2.6)	[1.1]	80	(5.0)	[1.2]
Dec	92	(2.9)	[1.6]	234	(4.1)	[2.6]

*All values in micrograms per cubic meter

TABLE 2-I

Kalispell-Evergreen Electric
Particulate Data*
Total Suspended Particulates, TSP
June 1980 - December 1982

	1980		1981		1982	
	Mean (Max)		Mean (Max)		Mean (Max)	
Jan	--	--	43	(75)	41	(52)
Feb	--	--	71	(152)	49	(77)
Mar	--	--	50	(95)	46	(52)
Apr	--	--	57	(113)	50	(94)
May	--	--	42	(90)	44	(64)
Jun	54	(91)	91	(170)	35	(55)
Jul	78	(135)	86	(110)	84	(94)
Aug	58	(100)	99	(159)	77	(176)
Sep	103	(169)	72	(139)	109	(176)
Oct	84	(138)	88	(151)	61	(100)
Nov	51	(89)	50	(92)	31	(36)
Dec	51	(65)	30	(46)	35	(47)

*All values in micrograms per cubic meter

TABLE 2-J

Bigfork
Particulate Data*
Total Suspended Particulates, TSP
Sulfates (SO₄) and Nitrates [NO₃]
July 1979 - December 1982

Month	Arithmetic Mean			Maximum Reading		
	TSP	(SO ₄)	[NO ₃]	TSP	(SO ₄)	[NO ₃]
Jul 79	54	(2.4)	[0.5]	67	(2.9)	[0.6]
Aug	47	(2.3)	[0.5]	103	(2.7)	[0.6]
Sept	38	(2.7)	[0.7]	53	(4.0)	[0.9]
Oct	42	(2.9)	[1.2]	57	(3.4)	[1.5]
Nov	40	(4.1)	[2.2]	47	(4.8)	[4.9]
Dec	41	(3.3)	[1.3]	112	(3.9)	[2.3]
Jan 80	60	(5.1)	[2.3]	102	(8.0)	[3.9]
Feb	40	(3.7)	[1.2]	88	(5.5)	[1.6]
March	27	(3.5)	[0.4]	35	(6.5)	[0.8]
April	37	(3.1)	[0.4]	67	(5.2)	[0.8]
May	28	(2.7)	[0.6]	32	(3.2)	[0.8]
June	29	(2.4)	[0.2]	44	(3.2)	[0.4]
July	42	(2.4)	[0.7]	81	(2.8)	[1.4]
Aug	33	(3.5)	[0.1]	52	(5.8)	[0.3]
Sep	51	(3.2)	[0.4]	93	(4.2)	[0.8]
Oct	45	(4.1)	[1.1]	63	(5.0)	[1.9]
Nov	38	(4.6)	[0.8]	44	(5.4)	[1.0]
Dec	73	(1.8)	[0.5]	134	(1.8)	[0.5]
Jan 81	35	(4.2)	[1.7]	48	(6.5)	[3.0]
Feb	36	(2.5)	[0.8]	75	(4.7)	[1.0]
Mar	26	(2.4)	[0.9]	42	(3.2)	[1.2]
April	22	(1.6)	[0.3]	37	(2.1)	[0.5]
May	21	(2.4)	[0.3]	40	(5.0)	[0.7]
June	29	(2.2)	[0.3]	56	(2.6)	[0.6]
July	37	(2.3)	[0.4]	42	(3.5)	[0.5]
Aug	57	(2.2)	[0.9]	84	(2.4)	[1.3]
Sep	49	(2.2)	[0.6]	109	(3.5)	[1.4]
Oct	26	(3.3)	[0.8]	35	(5.1)	[1.3]
Nov	29	(2.1)	[1.2]	54	(4.2)	[2.8]
Dec	20	(1.5)	[0.7]	30	(3.7)	[1.5]
Jan 82	22	(2.5)	[0.8]	35	(6.1)	[1.8]
Feb	41	(3.2)	[0.5]	54	(7.8)	[1.3]
Mar	42	(3.2)	[0.1]	80	(6.6)	[0.4]
Apr	21	(1.0)	[0.2]	33	(1.1)	[0.3]
May	25	(1.3)	[0.2]	36	(2.0)	[0.3]
Jun	27	--	--	35	--	--
Jul	34	--	--	78	--	--
Aug	28	(1.9)	[0.8]	44	(2.5)	[1.0]
Sep	26	(1.7)	[0.4]	45	(3.5)	[0.6]
Oct	24	(1.4)	[0.5]	40	(1.9)	[0.8]
Nov	16	(2.1)	[0.5]	24	(4.4)	[0.8]
Dec	42	(2.0)	[1.1]	65	(2.5)	[2.0]

*All values in micrograms per cubic meter

TABLE 2-K

Polson
Particulate Data*
Total Suspended Particulates, TSP
Sulfates (SO₄) and Nitrates [NO₃]
March 1979 - December 1982

Month	Arithmetic Mean			Maximum Reading		
	TSP	(SO ₄)	[NO ₃]	TSP	(SO ₄)	[NO ₃]
March 79	48	(3.3)	[2.0]	75	(5.0)	[3.3]
April	48	(2.7)	[1.2]	94	(4.0)	[1.7]
May	96	(2.7)	[0.9]	149	(3.1)	[1.2]
June	106	(2.7)	[1.0]	169	(3.6)	[1.8]
July	59	(2.2)	[0.7]	63	(2.8)	[1.0]
Aug	98	(2.4)	[0.6]	188	(2.7)	[0.8]
Sept	133	(3.2)	[1.0]	191	(4.3)	[1.3]
Oct	106	(2.9)	[1.4]	202	(3.5)	[1.6]
Nov	48	(4.6)	[3.9]	71	(6.6)	[5.4]
Dec	30	(2.7)	[1.6]	43	(3.5)	[3.4]
Jan 80	98	(4.1)	[2.1]	177	(5.4)	[3.5]
Feb	40	(3.9)	[1.5]	62	(5.0)	[2.3]
March	27	(3.8)	[0.9]	37	(5.2)	[2.8]
April	74	(3.5)	[0.9]	114	(4.5)	[1.2]
May	31	(2.7)	[0.5]	42	(3.1)	[0.8]
June	47	(3.0)	[0.4]	51	(3.2)	[0.5]
July	--	--	--	--	--	--
Aug	72	(4.8)	[0.2]	83	(6.6)	[0.7]
Sept	83	(4.9)	[0.8]	159	(6.6)	[1.2]
Oct	70	(5.1)	[1.6]	128	(6.0)	[2.6]
Nov	55	(3.6)	[1.5]	84	(4.7)	[2.5]
Dec	52	(3.1)	[0.6]	90	(3.7)	[1.7]
Jan 81	24	(2.9)	[1.7]	35	(4.6)	[3.4]
Feb	46	(3.1)	[0.9]	111	(6.2)	[1.3]
Mar	36	(2.4)	[0.8]	76	(4.0)	[1.6]
April	43	(2.3)	[0.5]	76	(2.8)	[0.6]
May	35	(2.9)	[0.6]	81	(6.6)	[1.1]
June	32	(2.5)	[0.3]	39	(3.0)	[0.4]
July	57	(2.8)	[0.7]	77	(3.1)	[0.8]
Aug	66	(2.9)	[0.8]	84	(3.4)	[1.1]
Sep	56	(3.0)	[0.8]	72	(3.8)	[0.9]
Oct	46	(3.4)	[1.0]	72	(5.2)	[1.5]
Nov	57	(1.8)	[1.6]	174	(3.5)	[3.8]
Dec	23	(1.7)	[1.4]	35	(3.8)	[2.6]
Jan 82	29	(3.1)	[1.3]	36	(5.1)	[2.9]
Feb	51	(3.6)	[1.0]	67	(7.2)	[2.8]
Mar	31	(1.8)	[0.2]	46	(3.0)	[0.4]
Apr	48	(1.5)	[0.4]	100	(2.6)	[0.6]
May	36	(2.1)	[0.5]	63	(3.4)	[0.9]
Jun	40	(2.9)	[1.1]	71	(3.4)	[1.2]
Jul	56	(2.7)	[0.8]	95	(3.4)	[1.2]
Aug	44	(2.7)	[0.8]	84	(3.5)	[1.1]
Sep	56	(2.3)	[0.6]	92	(4.4)	[1.1]
Oct	48	(1.5)	[1.1]	72	(2.6)	[2.5]
Nov	28	(2.4)	[1.0]	34	(7.0)	[2.6]
Dec	35	(2.3)	[1.3]	51	(4.8)	[2.1]

*All values in micrograms per cubic meter

TABLE 2-L

Ronan
Particulate Data*
Total Suspended Particulates, TSP
Sulfates (SO₄) and Nitrates [NO₃]
November 1978 - July 1980

Month	Arithmetic Mean			Maximum Reading		
	TSP	(SO ₄)	[NO ₃]	TSP	(SO ₄)	[NO ₃]
Nov 78	85	(4.1)	[2.0]	170	(6.5)	[4.2]
Dec	19	(3.4)	[1.0]	32	(4.1)	[2.4]
Jan 79	36	(6.9)	[3.8]	58	(10.8)	[6.3]
Feb	49	(4.2)	[2.5]	64	(8.1)	[6.6]
March	76	(3.9)	[2.2]	123	(5.3)	[4.1]
April	94	(2.1)	[0.8]	168	(3.8)	[1.5]
May	130	(1.9)	[0.9]	147	(2.6)	[1.4]
June	227	(2.0)	[0.8]	311	(2.0)	[1.0]
July	204	(2.2)	[0.9]	224	(2.4)	[1.1]
Aug	140	(2.1)	[0.7]	240	(3.2)	[1.2]
Sept	176	(2.3)	[0.9]	288	(2.8)	[1.3]
Oct	137	(2.5)	[1.3]	406	(2.9)	[1.6]
Nov	27	(3.4)	[2.6]	29	(4.8)	[6.3]
Dec	53	(3.0)	[2.1]	69	(4.5)	[4.1]
Jan 80	61	(4.3)	[1.9]	140	(7.5)	[2.7]
Feb	89	(3.8)	[2.8]	168	(4.6)	[5.6]
March	88	(4.0)	[0.5]	106	(5.4)	[0.6]
April	146	(2.5)	[0.4]	220	(3.6)	[0.9]
May	56	(2.9)	[0.8]	80	(3.1)	[0.9]
June	61	(3.4)	[0.6]	88	(4.1)	[0.8]
July	74	(3.7)	[0.4]	120	(4.5)	[0.6]

*All values in micrograms per cubic meter

TABLE 2-M

Ninepipe
Particulate Data*
Total Suspended Particulates, TSP
Sulfates (SO₄) and Nitrates [NO₃]
October 1980 - December 1982

Month	Arithmetic Mean			Maximum Reading		
	TSP	(SO ₄)	[NO ₃]	TSP	(SO ₄)	[NO ₃]
Oct 80	29	--	--	42	--	--
Nov	21	(2.8)	[1.4]	35	(2.8)	[1.4]
Dec	15	(1.6)	[0.6]	26	(1.9)	[1.0]
Jan 81	17	(2.2)	[2.0]	24	(4.0)	[3.4]
Feb	13	(2.3)	[0.8]	20	(4.9)	[1.6]
Mar	13	(1.3)	[0.5]	30	(2.6)	[1.2]
Apr	17	(1.2)	[0.4]	30	(1.5)	[0.6]
May	22	(2.0)	[0.5]	45	(4.4)	[0.9]
Jun	18	(1.4)	[0.4]	24	(1.8)	[0.5]
July	40	(1.1)	[0.6]	45	(1.2)	[0.7]
Aug	47	(1.6)	[0.7]	55	(2.1)	[1.1]
Sep	60	(1.5)	[0.7]	142	(2.0)	[1.0]
Oct	19	(1.8)	[0.7]	29	(3.2)	[1.2]
Nov	20	(1.4)	[1.0]	39	(1.7)	[1.8]
Dec	9	(0.5)	[0.8]	17	(1.2)	[3.0]
Jan 82	10	(2.1)	[0.9]	20	(6.5)	[2.1]
Feb	13	(2.3)	[1.1]	26	(6.6)	[3.4]
Mar	7	(1.0)	[0.3]	12	(2.4)	[0.5]
Apr	15	(0.4)	[0.2]	34	(1.0)	[0.5]
May	30	(0.8)	[0.3]	42	(1.0)	[0.4]
Jun	26	(0.9)	[0.6]	38	(1.3)	[0.8]
Jul	27	(0.4)	[0.5]	71	(1.0)	[0.8]
Aug	31	(0.7)	[0.6]	54	(1.3)	[0.8]
Sep	25	(0.6)	[0.4]	43	(1.1)	[0.8]
Oct	15	(0.5)	[0.7]	25	(0.9)	[1.4]
Nov	10	(1.8)	[0.8]	14	(6.3)	[2.1]
Dec	14	(1.8)	[1.5]	20	(4.8)	[3.3]

*All values in micrograms per cubic meter

TABLE 2-N

Tribal Particulate Data*
Total Suspended Particulate (TSP)
1982

Month	Ronan		St. Ignatius		Arlee		Evaro	
	Mean	(Max)	Mean	(Max)	Mean	(Max)	Mean	(Max)
Jan 82	41	(50)	33	(44)	21	(36)	14	(15)
Feb	149	(272)	63	(100)	13	(17)	29	(48)
Mar	84	(122)	56	(98)	19	(23)	28	(32)
Apr	110	(176)	59	(105)	29	(47)	36	(67)
May	82	(134)	68	(87)	32	(47)	93	(84)
Jun	77	(135)	52	(92)	44	(77)	35	(55)
Jul	88	(206)	82	(132)	186	(772)	48	(114)
Aug	68	(110)	110	(167)	25	(39)	58	(94)
Sep	84	(153)	94	(187)	--	--	93	(77)
Oct	60	(101)	86	(154)	17	(32)	26	(43)
Nov	40	(77)	39	(70)	10	(15)	16	(23)
Dec	59	(104)	139	(172)	14	(25)	23	(40)

*All values in micrograms per cubic meter

TABLE 2-0

Swan River Youth Camp
 Particulate Data*
 Total Suspended Particulates, TSP
 Sulfates (SO₄) and Nitrates [NO₃]
 1982

Month	Arithmetic Mean			Maximum Reading		
	TSP	(SO ₄)	[NO ₃]	TSP	(SO ₄)	[NO ₃]
Jan 82	18	(2.8)	[0.1]	46	(5.4)	[0.2]
Feb	6	(4.0)	[0.0]	9	(5.6)	[0.0]
Mar	7	(2.2)	[0.0]	12	(3.0)	[0.0]
Apr	25	(2.4)	[0.0]	58	(3.8)	[0.0]
May	48	(3.4)	[0.1]	85	(5.2)	[0.3]
Jun	59	(4.1)	[0.4]	144	(4.7)	[0.4]
Jul	101	(2.4)	[0.3]	196	(3.5)	[0.5]
Aug	98	(1.3)	[0.3]	306	(1.7)	[0.5]
Sep	169	(2.6)	[0.3]	236	(3.0)	[0.4]
Oct	13	(2.2)	[0.1]	27	(3.2)	[0.2]
Nov	37	(3.0)	[0.1]	122	(6.5)	[0.2]
Dec	4	(2.5)	[0.1]	8	(3.9)	[0.2]

*All values in micrograms per cubic meter

TABLE 3-A

Polebridge
Fine Particulate Data*
Monthly Means and Maximums
September 1978 - December 1979

Month	Less than 2.5 microns		2.5 to 15 microns		Less than 15 microns	
	Mean	Maximum	Mean	Maximum	Mean	Maximum
Sept 78	14.1	21.1	6.3	7.0	20.4	26.5
Oct	13.4	24.1	6.5	13.2	19.9	36.8
Nov	9.5	15.7	5.3	7.3	14.9	23.0
Dec	6.5	8.1	2.6	3.2	9.1	11.2
Jan 79	7.9	9.9	2.2	2.4	10.0	12.0
Feb	5.2	9.5	0.8	1.4	6.0	9.5
March	6.7	9.5	1.4	2.6	8.1	12.1
April	8.3	16.0	5.7	19.4	14.0	35.4
May	7.4	9.4	6.4	10.7	13.8	20.2
June	5.1	7.0	13.2	24.1	18.3	38.4
July	10.2	17.3	46.8	88.6	57.0	106.0
Aug	11.7	11.7	24.7	25.1	36.4	36.7
Sept	10.6	14.7	18.0	19.6	28.6	32.7
Oct	14.2	24.7	7.2	16.1	23.4	33.4
Nov	16.2	22.5	4.5	10.6	20.7	27.1
Dec	4.3	4.4	3.7	5.4	8.0	9.8

*All values in micrograms per cubic meter

TABLE 3-B

Columbia Falls - Anders
Fine Particulate Data*
Monthly Means and Maximums
January 1980 - October 1980

Month	Less than 2.5 microns		2.5 to 15 microns		Less than 15 microns	
	Mean	Maximum	Mean	Maximum	Mean	Maximum
Jan 80	26.1	28.4	31.6	62.7	57.8	87.7
Feb	17.7	23.5	6.1	6.4	23.8	29.3
March	8.1	9.0	39.9	96.0	44.8	105.0
April	11.2	13.5	102.5	118.1	113.7	129.1
May	10.8	12.5	46.3	92.2	57.1	103.7
June	11.6	15.0	31.9	38.1	43.5	165.6
July	16.6	28.0	82.6	197.3	99.2	223.8
Aug	10.6	14.0	47.1	90.8	53.3	102.8
Sep	14.6	24.5	82.1	136.6	97.6	161.1
Oct	23.8	28.0	163.8	235.5	137.4	263.5

*All values in micrograms per cubic meter

TABLE 3-C

Kalispell - Airport
Fine Particulate Data*
Monthly Means and Maximums
September 1978 - December 1980

Month	Less than 2.5 microns		2.5 - 15 microns		Less than 15 microns	
	Mean	Maximum	Mean	Maximum	Mean	Maximum
Sept. 78	15.0	16.7	15.7	24.0	30.7	41.1
Oct.	22.4	40.4	28.2	44.7	50.6	85.1
Nov.	--	--	--	--	--	--
Dec.	--	--	--	--	--	--
Jan. 79	--	--	--	--	--	--
Feb. **	9.9	9.9	11.7	11.7	21.6	21.6
March**	9.4	9.4	6.3	6.3	15.7	15.7
April	10.8	23.0	18.8	54.0	29.6	77.1
May	11.6	15.0	25.9	39.8	37.6	50.8
June	11.4	17.0	29.3	61.5	40.7	73.7
July	13.5	19.7	31.1	43.4	44.6	63.1
August	12.2	28.7	24.0	43.3	36.1	72.0
Sept.	19.4	28.7	32.7	48.8	52.1	77.5
Oct.	36.6	41.4	59.7	68.1	96.3	109.5
Nov.	--	--	--	--	--	--
Dec.	12.7	18.0	10.9	21.6	23.7	34.3
Jan. 80	--	--	--	--	--	--
Feb.	--	--	--	--	--	--
March	7.1	10.8	14.9	39.3	22.0	50.1
April	10.4	14.3	24.8	43.7	35.2	58.0
May	10.2	13.8	22.8	45.1	33.0	58.9
June	12.5	23.0	37.1	109.9	49.6	132.9
July	17.8	27.2	50.3	100.5	68.1	121.5
Aug	14.0	23.9	47.0	174.3	61.0	198.2
Sept	17.3	24.1	47.1	84.1	64.5	108.3
Oct	--	--	--	--	--	--
Nov**	9.7	9.7	14.9	14.9	24.6	24.6
Dec	13.0	25.1	11.7	21.5	24.7	37.4

*All values in micrograms per cubic meter

**one value only

TABLE 3-D

Kalispell - Universal Athletics
Fine Particulate Data*
Monthly Means and Maximums
January 1980 - December 1980

Month	Less than 2.5 microns		2.5 to 15 microns		Less than 15 microns	
	Mean	Maximum	Mean	Maximum	Mean	Maximum
Jan 80	32.0	42.3	22.8	44.0	54.8	71.5
Feb	23.9	28.2	31.4	54.6	55.3	82.8
March	14.4	17.3	44.2	63.6	58.6	78.5
April	13.1	16.8	46.4	71.9	59.5	88.7
May	8.8	10.7	40.4	63.8	49.2	70.3
June	8.6	10.4	45.4	52.0	54.0	62.4
July	10.4	12.5	40.8	61.8	51.2	74.3
Aug	9.7	14.4	43.5	53.9	53.2	58.9
Sep	15.9	18.8	58.6	84.2	74.6	103.1
Oct	19.5	25.3	37.6	56.0	57.1	71.6
Nov	27.6	33.3	42.3	52.6	69.9	75.7
Dec	23.6	42.9	44.1	144.3	67.7	187.2

*All values in micrograms per cubic meter

TABLE 3-E

Polson
Fine Particulate Data*
Monthly Means and Maximums
September 1978 - August 1980

Month	Less than 2.5 microns		2.5 - 15 microns		Less than 15 microns	
	Mean	Maximum	Mean	Maximum	Mean	Maximum
Sep 78	15.1	16.8	21.8	29.8	36.9	46.6
Oct	16.1	30.4	49.9	90.1	65.9	99.6
Nov	14.1	27.3	19.9	29.3	34.0	53.5
Dec	8.7	9.6	14.1	20.0	22.8	27.2
Jan 79	--	--	--	--	--	--
Feb	--	--	--	--	--	--
Mar	--	--	--	--	--	--
April	15.9	24.0	34.3	52.4	50.1	76.4
May	26.1	76.7	39.1	89.9	65.1	105.7
June	13.2	22.1	47.8	90.7	61.0	102.7
July	8.3	10.1	29.1	33.1	37.4	43.2
Aug	10.7	14.4	59.8	143.9	70.5	158.2
Sept	15.6	24.9	68.1	100.6	83.8	125.5
Oct	19.6	24.9	39.7	74.0	59.3	92.4
Nov	--	--	--	--	--	--
Dec	--	--	--	--	--	--
Jan 80	12.1	17.8	38.4	59.3	50.5	77.1
Feb	14.1	14.1	14.2	14.2	28.3	28.3
March	1.3	1.6	11.9	30.1	13.2	30.6
April	7.8	14.0	19.4	33.3	28.0	44.0
May	10.4	14.6	26.6	54.7	36.9	66.5
June	7.6	10.2	19.6	25.2	27.5	35.4
July	16.9	24.8	47.0	84.3	63.9	109.1
Aug	27.0	27.0	26.1	26.1	53.1	53.1

*All values in micrograms per cubic meter

TABLE 3-F

Ninepipe
Fine Particulate Data*
Monthly Means and Maximums
January 1981 - December 1981

Month	Less than 2.5 microns		2.5 to 15 microns		Less than 15 microns	
	Mean	Maximum	Mean	Maximum	Mean	Maximum
Jan	7.2	8.8	5.5	10.5	12.7	16.7
Feb	5.9	13.4	8.0	27.9	13.9	31.1
Mar	4.8	10.3	3.5	5.3	8.3	15.6
Apr	2.3	2.6	21.8	66.0	24.1	68.8
May	3.9	9.2	8.7	16.6	12.6	25.8
Jun	3.6	5.1	8.6	10.8	12.2	15.9
Jul	6.9	7.3	24.9	29.7	31.8	37.0
Aug	--	--	--	--	--	--
Sep	25.8	44.8	22.4	38.8	48.2	83.6
Oct	7.8	10.6	8.7	13.5	16.5	21.4
Nov	9.8	19.1	4.5	9.7	14.3	28.8
Dec	5.3	13.5	3.3	6.2	8.6	16.0

*All values in micrograms per cubic meter

TABLE 4-A

Kalispell - Airport (GIA)
 Visibility Data (Nephelometer)
 Scattering Coefficients x 10⁻⁵
 Monthly Means, Maximum Days, and Maximum Hours

<u>Month</u>	1978			1979			1980		
	<u>Mean</u>	<u>Max Day</u>	<u>Max Hour</u>	<u>Mean</u>	<u>Max Day</u>	<u>Max Hour</u>	<u>Mean</u>	<u>Max Day</u>	<u>Max Hour</u>
Jan	16.9	28.4	61.7	34.1	50.2	73.2	18.0	38.7	57.1
Feb	20.3	42.0	52.5	16.9	69.7	83.6	23.8	61.7	72.1
Mar	14.9	26.1	37.6	14.6	26.1	42.2	8.9	26.1	42.2
Apr	10.1	15.3	26.1	10.0	19.2	33.0	6.6	11.1	26.1
May	9.7	15.6	22.6	8.9	13.4	28.4	--	--	--
Jun	--	--	--	10.0	13.4	21.5	4.6	8.5	16.9
Jul	--	--	--	12.3	24.9	46.8	5.2	16.0	42.3
Aug	--	--	--	--	--	--	4.9	9.1	14.1
Sep	7.7	16.9	30.7	--	--	--	6.7	13.9	23.8
Oct	15.7	28.4	44.5	12.3	27.2	50.2	13.7	30.3	70.9
Nov	15.7	38.7	57.1	21.5	38.7	50.2	10.5	22.8	35.1
Dec	13.4	28.4	52.5	13.4	36.4	49.1	12.3	26.3	70.7

<u>Month</u>	1981			1982		
	<u>Mean</u>	<u>Max Day</u>	<u>Max Hour</u>	<u>Mean</u>	<u>Max Day</u>	<u>Max Hour</u>
Jan	--	--	--	6.7	17.8	33.9
Feb	--	--	--	6.7	20.4	36.4
Mar	--	--	--	3.0	7.9	17.3
Apr	--	--	--	3.4	7.7	30.3
May	4.4	9.5	20.2	1.9	4.0	8.2
Jun	2.1	4.5	7.7	3.1	11.5	16.2
Jul	4.8	8.8	23.5	3.3	7.9	19.8
Aug	5.4	15.1	25.9	2.4	4.5	12.6
Sep	3.3	13.2	31.4	3.1	9.3	21.6
Oct	9.5	26.4	39.8	7.2	24.5	55.4
Nov	11.6	30.1	53.5	6.3	18.4	38.4
Dec	9.2	25.8	43.5	6.3	15.8	28.9

TABLE 4-8

Ninepipe
 Visibility Data (Nephelometer)
 Scattering Coefficients $\times 10^{-5}$
 Monthly Means, Maximum Days, and Maximum Hours

<u>Month</u>	<u>Mean</u>	1981 <u>Max Day</u>	<u>Max Hour</u>	<u>Mean</u>	1982 <u>Max Day</u>	<u>Max Hour</u>
Jan	--	--	--	3.7	11.2	26.6
Feb	--	--	--	4.3	13.6	35.9
Mar	--	--	--	2.1	5.0	14.2
Apr	--	--	--	2.1	5.0	19.3
May	--	--	--	2.7	4.0	6.5
Jun	--	--	--	5.6	12.0	14.7
Jul	3.0	5.8	12.4	2.1	5.1	13.7
Aug	4.7	12.1	26.8	2.3	7.8	34.7
Sep	--	--	--	2.1	9.2	13.4
Oct	5.2	15.2	43.7	3.0	9.0	13.5
Nov	2.1	4.7	12.6	4.3	10.8	21.1
Dec	3.8	13.0	29.1	4.4	11.5	21.1

METEOROLOGY

A. General Methodology

The third goal of the air quality portion of the Flathead Basin Environmental Impact Study was to quantify the meteorology of the Basin at both low and high altitudes. The Air Quality Bureau accomplished this goal by installing and operating an extensive network of surface and upper air meteorological monitoring sites. The Air Quality Bureau purchased the meteorological equipment and supported the network by providing supplies, repair services, spare parts, training, and data processing services. The actual day to day operation of the network was accomplished by private contractors.

B. Surface Wind

From January 1980 through December 1982 surface wind data was collected at five sites in the Flathead River Basin. Surface wind data was also collected in 1978 and 1979 at these sites, plus another site near Columbia Falls. Data from 1978 and 1979 was included in earlier reports (Coefield, 1981 and Gelhaus, 1979). In general, surface winds throughout the Basin are light and tend to be oriented north-south along the valley axis. A site by site comparison of wind monitoring sites and results follows.

1. Big Prairie - site 480_308.

The Big Prairie site was located inside Glacier National Park in a large open meadow ("Big Prairie") about three kilometers north of the Polebridge Ranger Station on the east side of the North Fork of the Flathead River. A wind speed and direction sensor was mounted on a ten meter tower.

Data was collected at Big Prairie from November 1978 through June 1982. The installation was very remote and the monitor was powered by a car battery which was changed monthly. This system would not operate in very cold temperatures

and the winter data, especially for December, January and February was not usable. Access to the site was also difficult as no motor vehicle traffic was allowed to the site during the winter months.

Monthly, quarterly, and annual wind roses for this site are presented in Figures 3-A through 3-K. Wind speeds at this site were extremely low, with more than 50 percent of the readings less than 1.5 meters per second. The average wind speed was 1.6 meters per second. The wind direction at this site was bi-modal with most of the winds blowing from either the north northwest or south southeast. This closely matches the valley orientation and was not unexpected for a site with such rugged terrain. The fastest wind speeds came from the west and were due to frontal movements through the area.

2. Glacier International Airport - site 480_304.

The GIA site was located east of the private hangars at the Glacier International Airport 13 kilometers north northeast of Kalispell. The wind speed and direction sensors were located on a ten meter tower. The site was located in a wide valley with mountains to the west, north and east and Flathead Lake to the south. There were no obstructions to airflow near the site.

The wind system operated from June 1978 through June 1983. The sensor was monitored by a computer based data acquisition system which stored the data in a digital format on magnetic diskette for central processing.

Monthly, quarterly and annual wind roses for the site are presented in Figures 4-A through 4-N. Winds were quite light at this site, with an average wind speed of 2.2 meters per second. Wind direction at this site was bi-modal with most of the winds northerly or southerly, in alignment with the terrain. The highest wind speeds came from the northeast and result from wind funneling out of Bad Rock Canyon during polar outbreaks.

3. Bigfork - site 480 036.

The Bigfork site was located at the Bigfork District Ranger Station on a hill just northwest of Bigfork. The wind speed and direction sensors were attached to a ten meter tower. The surrounding terrain was complex with Flathead Lake to the south and west, rolling hills to the north and east, and the north end of the Mission Mountain Range to the southeast.

The wind system operated from November 1979 through December 1982. The sensor data was recorded on a chart and later digitized by hand for central processing.

Monthly, quarterly and annual wind roses for this site are presented in Figures 5-A through 5-L. Wind speeds were very low with an overall average of 1.7 meters per second. The data suggested the presence of a land/lake breeze effect with wind frequency maxima from the north through northeast balanced by a second maxima from the south through southwest. The southerly lake breeze also produced the highest wind speeds at this site.

4. Polson - site 820 010.

The Polson site was located three and one half kilometers east of Polson and one and one half kilometers south of Flathead Lake. The wind speed and direction sensor was located on a ten meter tower. The surrounding terrain was moderately complex with rolling hills to the south and west, the Mission Mountains seven kilometers to the east and Flathead Lake to the north.

The wind system operated from October 1978 through December 1982. The sensor data was recorded on a chart and later digitized by hand for central processing.

Monthly, quarterly, and annual wind roses for this site are presented in Figures 6-A through 6-L. Wind speeds at the site were low with an overall

average of 2.4 meters per second. There were very strong wind direction frequency maxima from the south southeast through south southwest with up to 55 percent of the winds coming from these directions per year. These maxima are partially balanced by a smaller frequency maxima from the north northwest to north northeast. These directions also produced the strongest winds. This strong preference in direction was probably caused by a combination of terrain influences and a land/lake breeze effect.

5. Ninepipe - site_820_012.

The Ninepipe site was located just north of Ninepipe Reservoir about eight kilometers south of Ronan. The wind speed and direction sensor was attached to a 13-meter tower. The terrain around the site was very level, however the Mission Mountains rose abruptly about nine kilometers to the east and rolling hills started about 15 kilometers to the west.

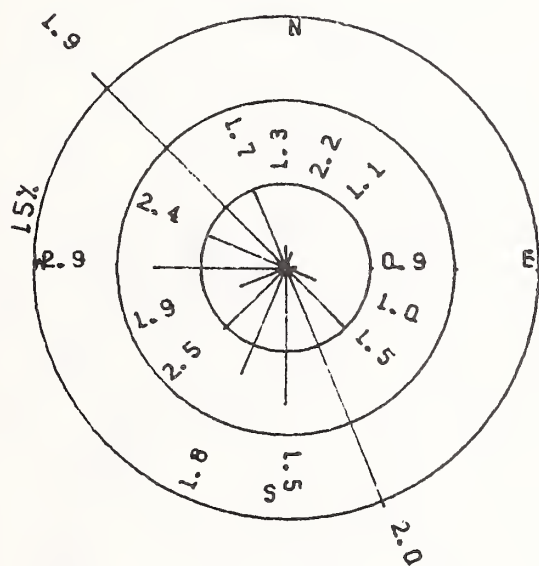
The wind system operated from December 1980 through June 1983. The sensor was computer monitored and the data was stored on site in digital format for central processing.

Monthly, quarterly and annual wind roses for this site are presented in Figures 7-A through 7-K. Wind speeds here were low, with an overall average of 2.0 meters per second. There was a strong maximum in wind direction frequencies from the south through the southeast. These directions also produced the highest average wind speeds.

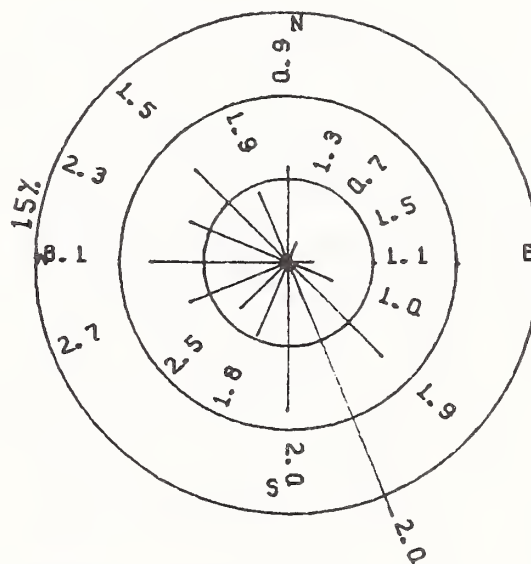
SURFACE WIND ROSES

SITE: 480308 BIG PRAIRIE MONTHLY

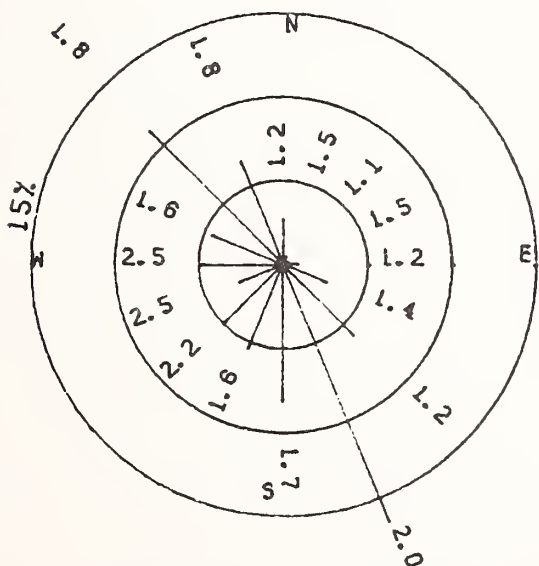
POLEBRIDGE MONTANA



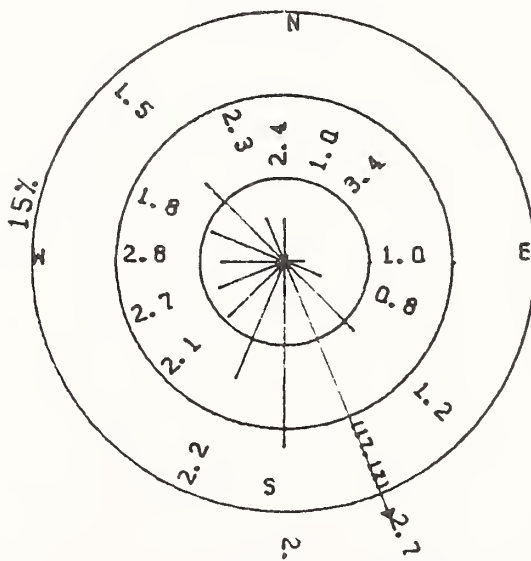
JUNE 1980
HOURS 0 TO 23
CALM 17.9%
(TOTAL HOURS 253)



JULY 1980
HOURS 0 TO 23
CALM 13.2%
(TOTAL HOURS 636)



AUGUST 1980
HOURS 0 TO 23
CALM 21.3%
(TOTAL HOURS 583)



SEPTEMBER 1980
HOURS 0 TO 23
CALM 25.2%
(TOTAL HOURS 320)

FIGURE 3-A

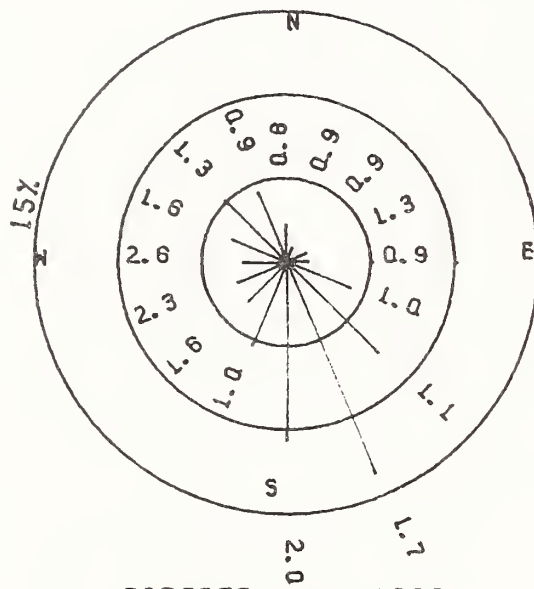
SURFACE WIND ROSES

SITE: 480308 BIG PRAIRIE

MONTHLY

POLEBRIDGE

MONTANA

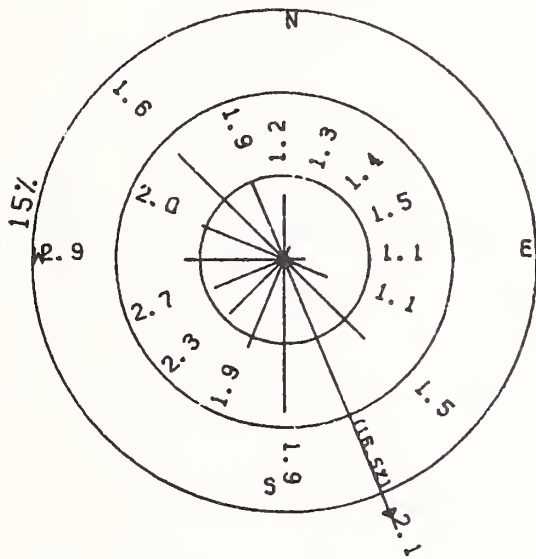


SURFACE WIND ROSES

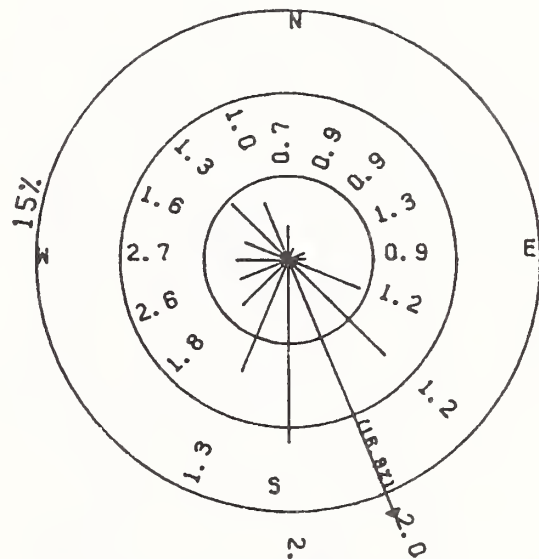
SITE: 480308 BIG PRAIRIE

QUARTERLY

POLEBRIDGE MONTANA



JULY - Sept 1980
HOURS 0 TO 23
CALM 19.1%
(TOTAL HOURS 1539)



OCTOBER - Nov 1980
HOURS 0 TO 23
CALM 26.5%
(TOTAL HOURS 502)

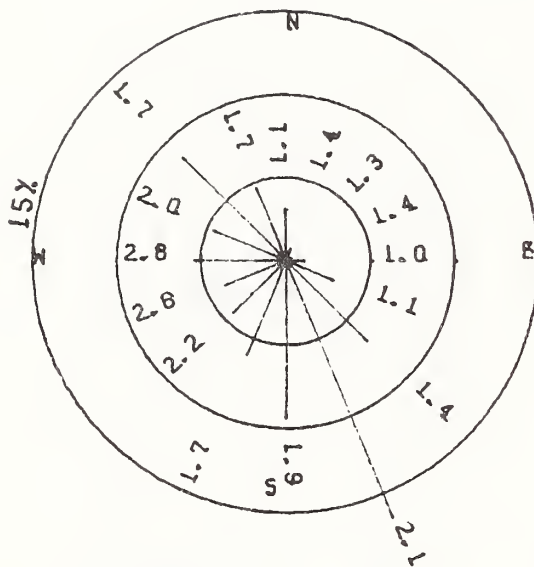
FIGURE 3-C

SURFACE WIND ROSES

SITE: 480308 BIG PRAIRIE

ANNUAL

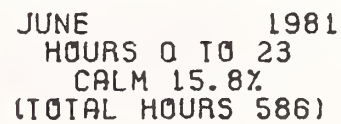
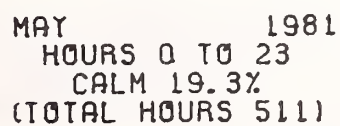
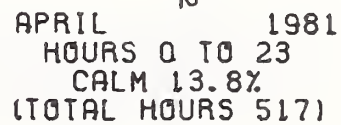
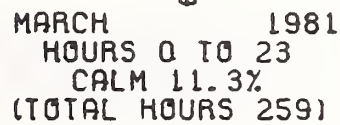
POLEBRIDGE MONTANA



JUNE - Nov. 1980
HOURS 0 TO 23
CALM 20.7%
(TOTAL HOURS 2294)

FIGURE 3-D

POLEBRIDGE MONTANA



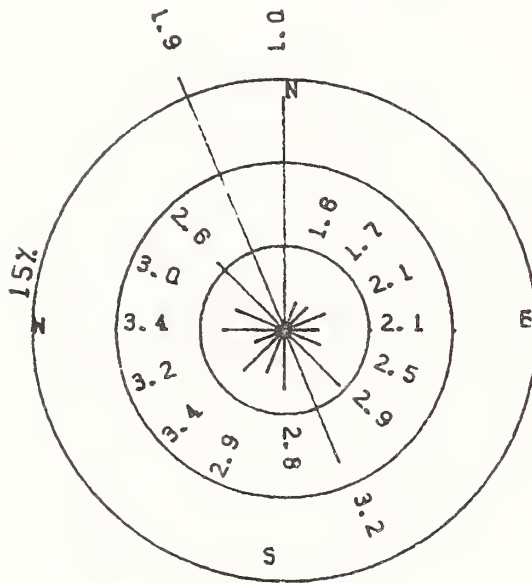
55

SURFACE WIND ROSES

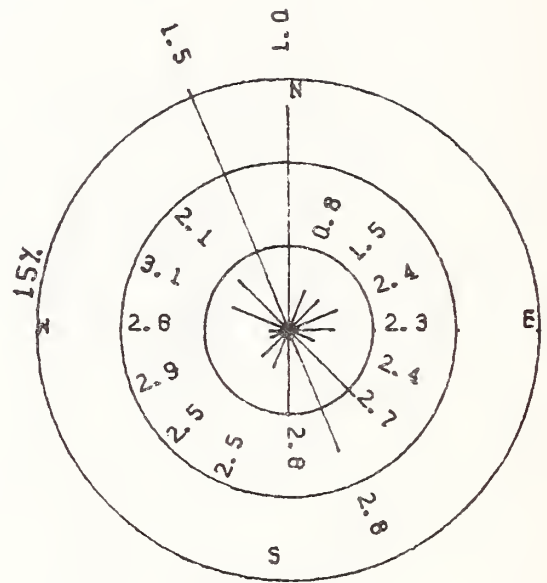
SITE: 480308 BIG PRAIRIE

MONTHLY

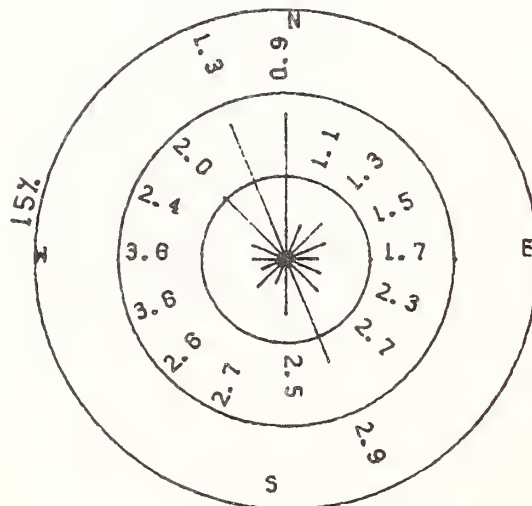
POLEBRIDGE MONTANA



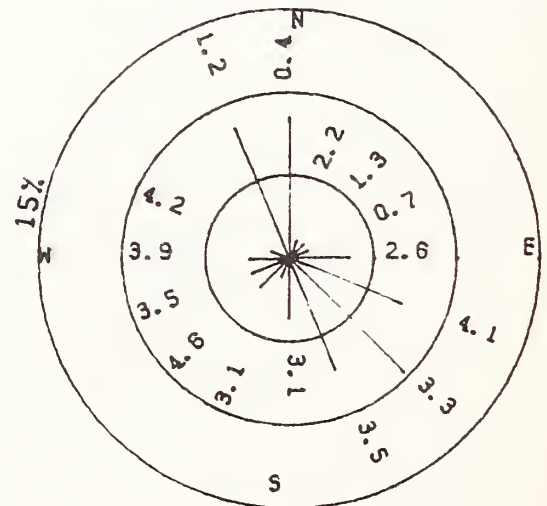
JULY 1981
HOURS 0 TO 23
CALM 22.1%
(TOTAL HOURS 569)



AUGUST 1981
HOURS 0 TO 23
CALM 25.6%
(TOTAL HOURS 498)



SEPTEMBER 1981
HOURS 0 TO 23
CALM 43.0%
(TOTAL HOURS 360)



OCTOBER 1981
HOURS 0 TO 23
CALM 38.6%
(TOTAL HOURS 51)

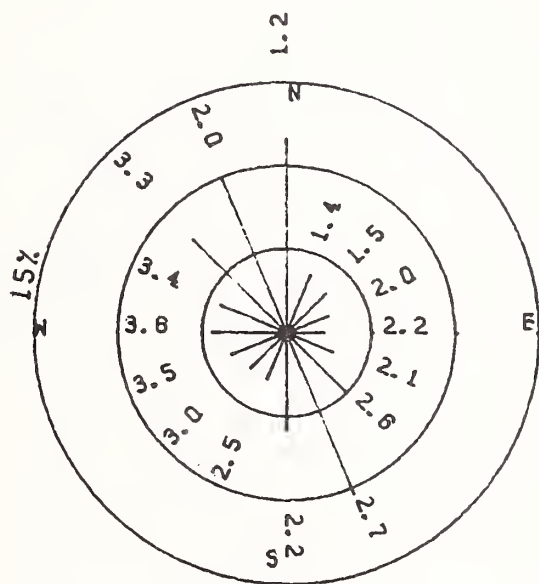
FIGURE 3-F

SURFACE WIND ROSES

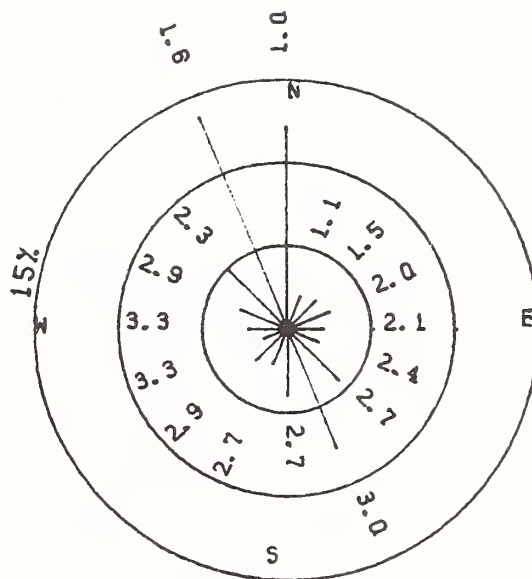
SITE: 480308 BIG PRAIRIE

QUARTERLY

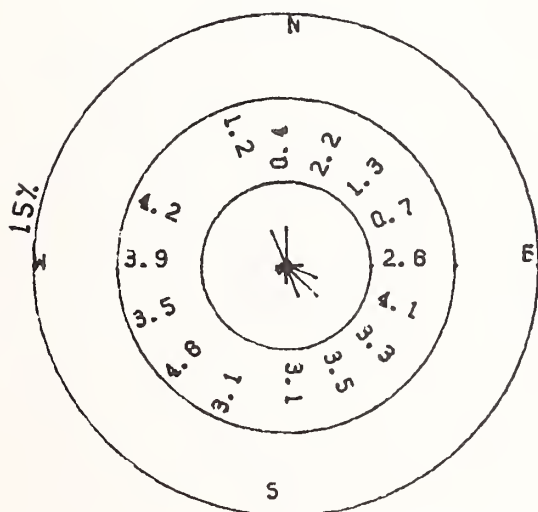
POLEBRIDGE MONTANA



APRIL - June 1981
HOURS 0 TO 23
CALM 16.3%
(TOTAL HOURS 1614)



JULY - Sept 1981
HOURS 0 TO 23
CALM 29.7%
(TOTAL HOURS 1427)



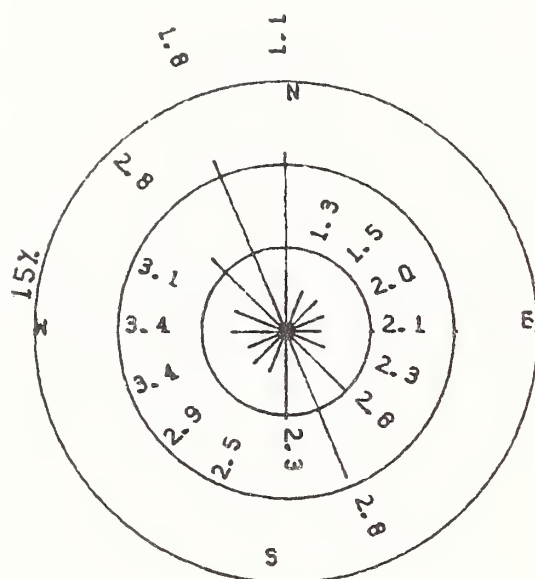
OCTOBER 1981
HOURS 0 TO 23
CALM 83.3%
(TOTAL HOURS 51)

FIGURE 3-G

SURFACE WIND ROSES

SITE: 480308 BIG PRAIRIE ANNUAL

POLEBRIDGE MONTANA

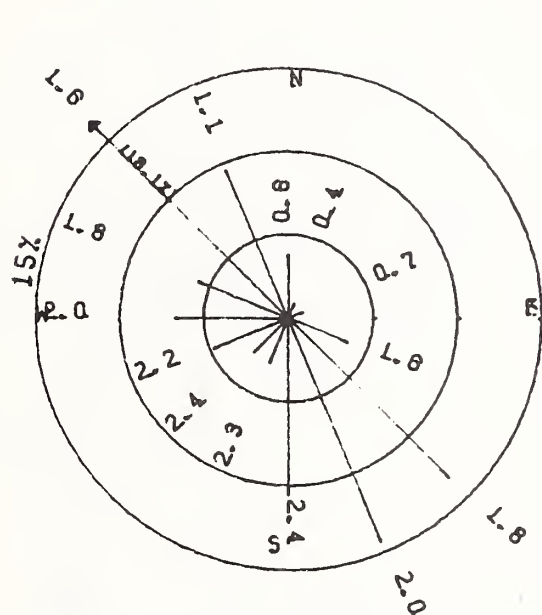


MARCH - Oct 1981
HOURS 0 TO 23
CALM 26.5%
(TOTAL HOURS 3351)

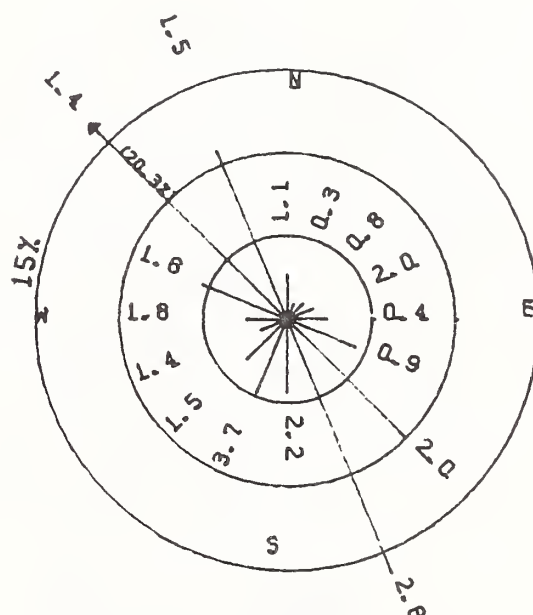
FIGURE 3-H

SURFACE WIND ROSES

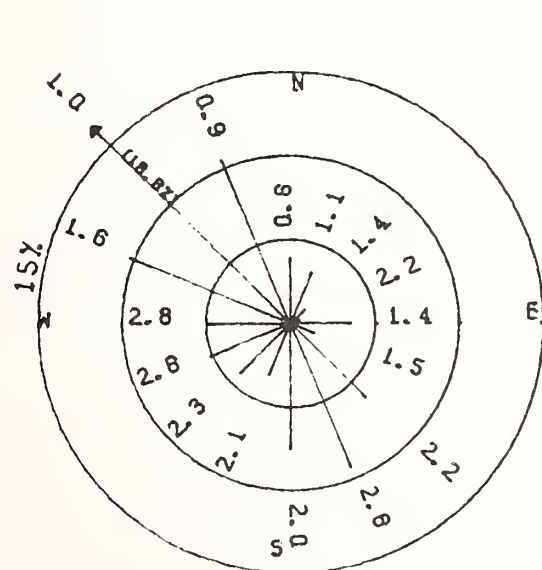
SITE: 480308 BIG PRAIRIE MONTHLY
POLEBRIDGE MONTANA



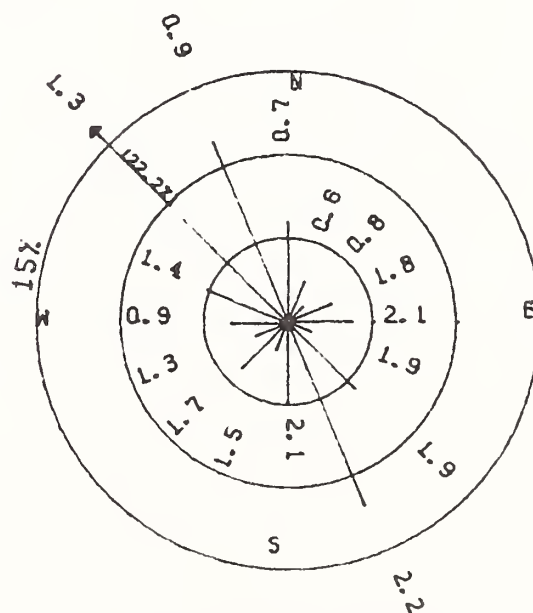
MARCH 1982
HOURS 0 TO 23
CALM 1.9%
(TOTAL HOURS 103)



APRIL 1982
HOURS 0 TO 23
CALM 7.1%
(TOTAL HOURS 274)



MAY 1982
HOURS 0 TO 23
CALM 6.3%
(TOTAL HOURS 313)



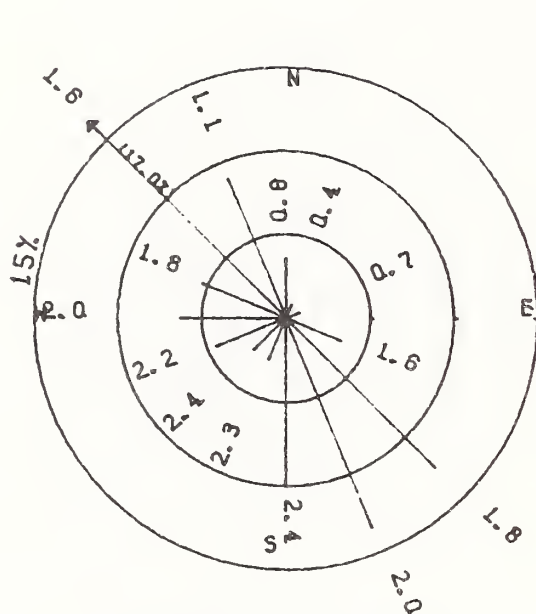
JUNE 1982
HOURS 0 TO 23
CALM 9.3%
(TOTAL HOURS 351)

FIGURE 3-I

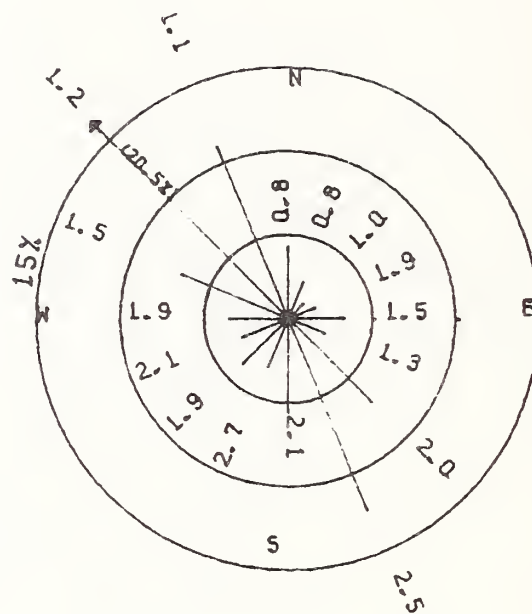
SURFACE WIND ROSES

SITE: 480308 BIG PRAIRIE QUARTERLY

POLEBRIDGE MONTANA



JANUARY - Mar 1982
HOURS 0 TO 23
CALM 8.0%
(TOTAL HOURS 103)



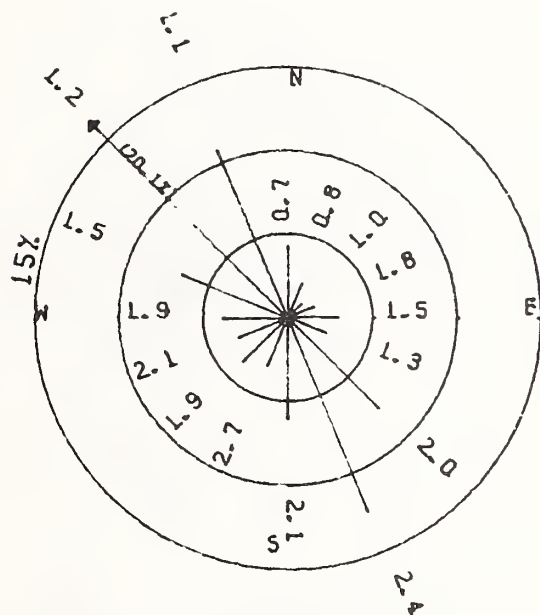
APRIL - June 1982
HOURS 0 TO 23
CALM 7.7%
(TOTAL HOURS 938)

FIGURE 3-J

SURFACE WIND ROSES

SITE: 480308 BIG PRAIRIE ANNUAL

POLEBRIDGE, MONTANA



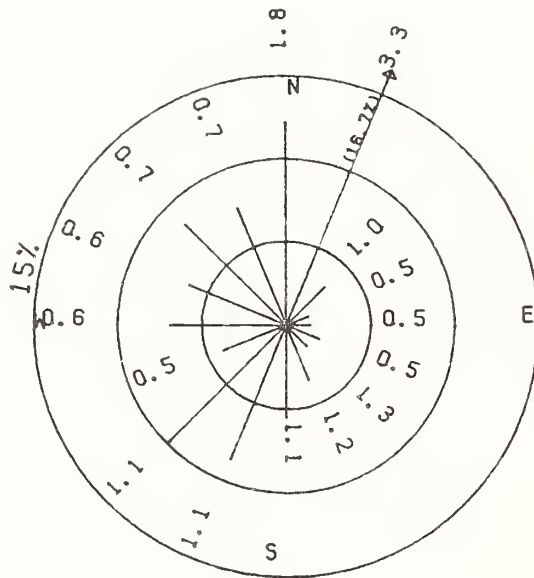
March - June 1982
HOURS 0 TO 23
CALM 7.7%
(TOTAL HOURS 1041)

FIGURE 3-K

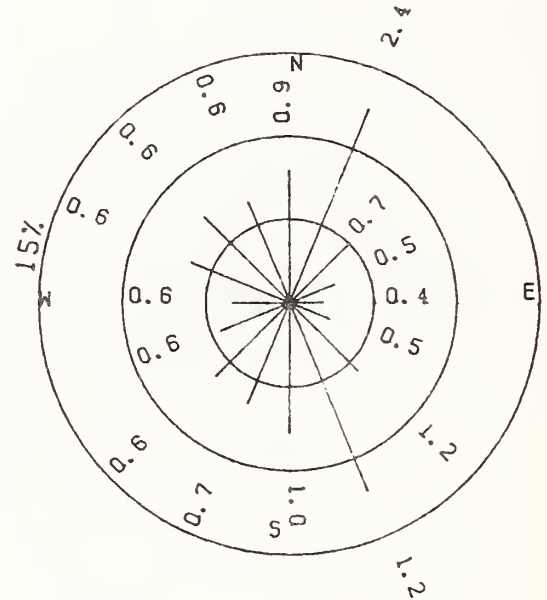
SURFACE WIND ROSES

SITE: 480304 FLATHEAD AIRPORT (GIA) MONTHLY

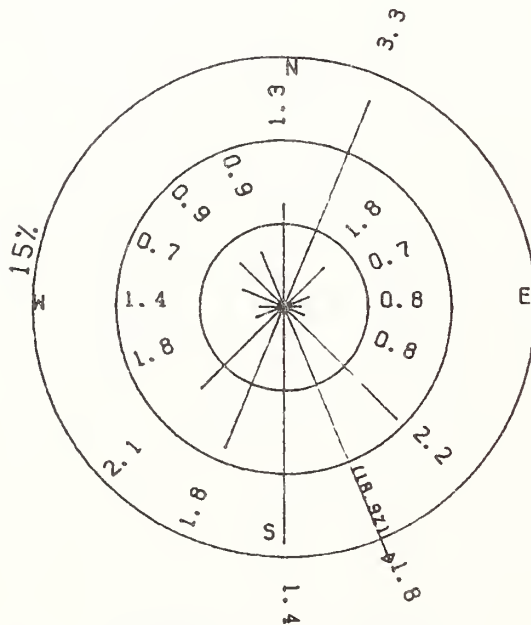
KALISPELL MONTANA



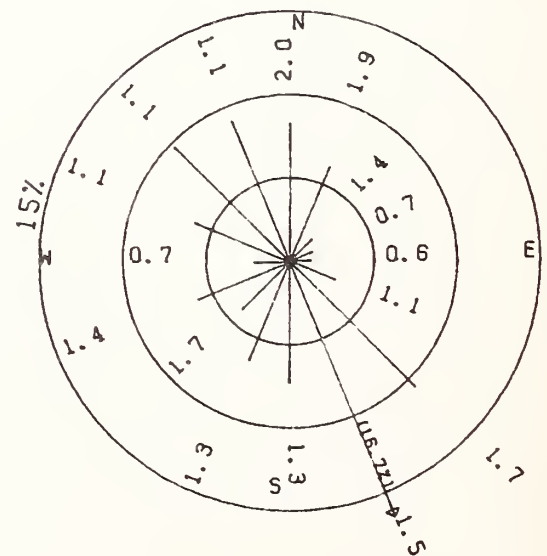
JANUARY 1980
HOURS 0 TO 23
CALM 0.4%
(TOTAL HOURS 739)



FEBRUARY 1980
HOURS 0 TO 23
CALM 1.0%
(TOTAL HOURS 689)



MARCH 1980
HOURS 0 TO 23
CALM 1.5%
(TOTAL HOURS 668)



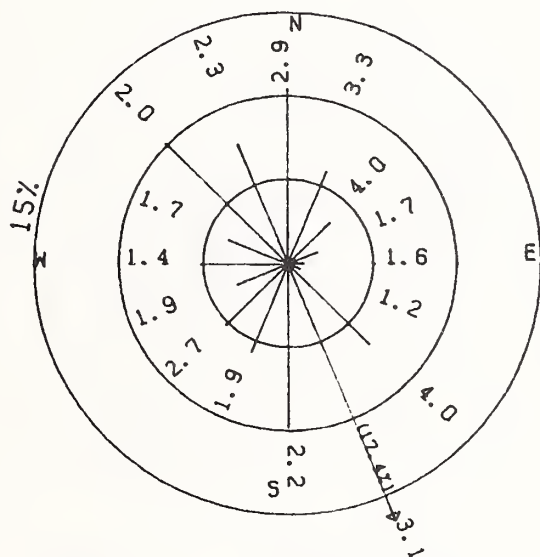
APRIL 1980
HOURS 0 TO 23
CALM 0.2%
(TOTAL HOURS 472)

FIGURE 4-A

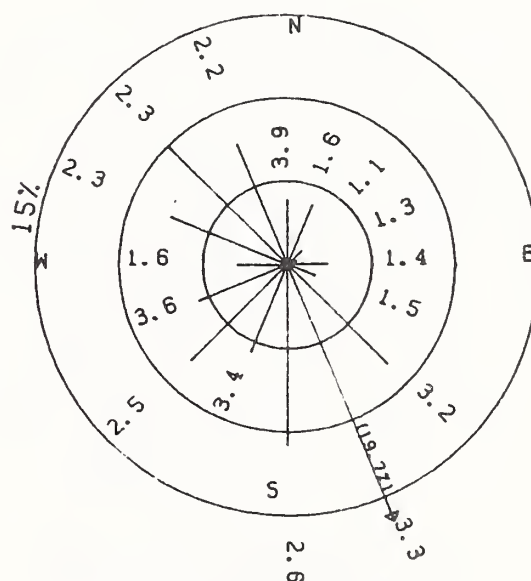
SURFACE WIND ROSES

SITE: 480304 FLATHEAD AIRPORT (GIA) MONTHLY

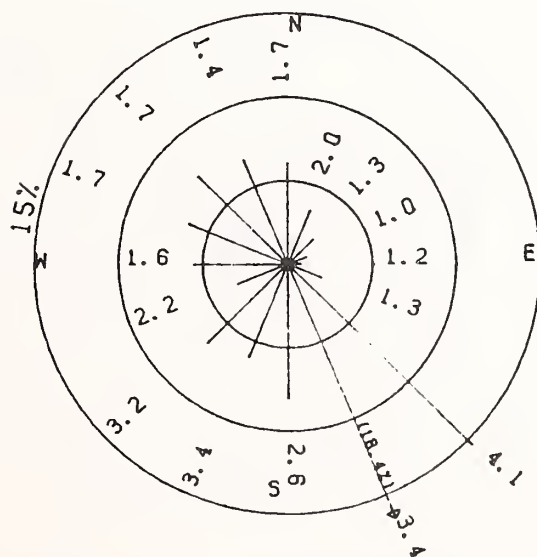
KALISPELL MONTANA



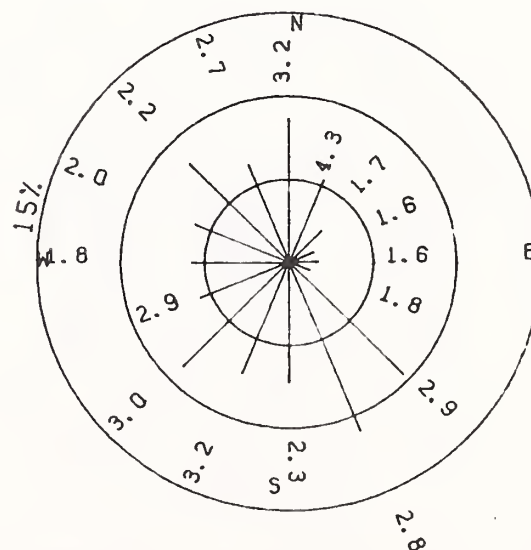
MAY 1980
HOURS 0 TO 23
CALM 1.9%
(TOTAL HOURS 727)



JUNE 1980
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 335)



JULY 1980
HOURS 0 TO 23
CALM 0.4%
(TOTAL HOURS 741)



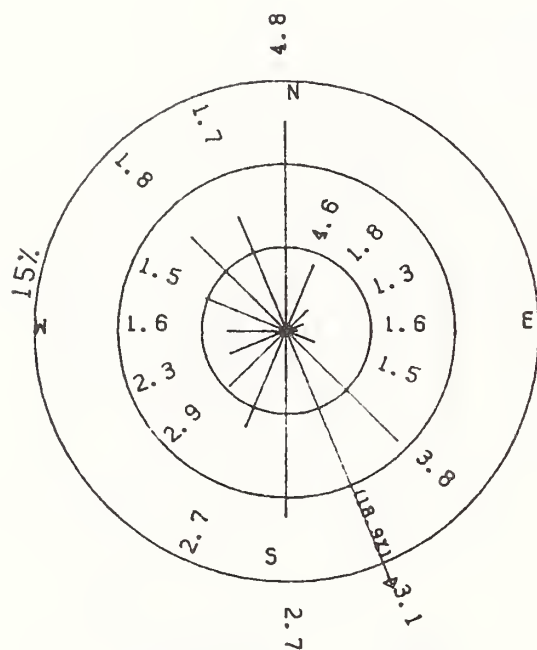
AUGUST 1980
HOURS 0 TO 23
CALM 2.6%
(TOTAL HOURS 725)

FIGURE 4-B

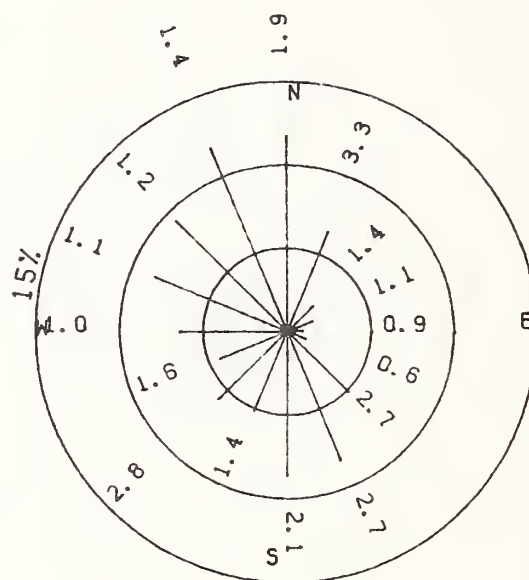
SURFACE WIND ROSES

SITE: 480304 FLATHEAD AIRPORT (GIA) MONTHLY

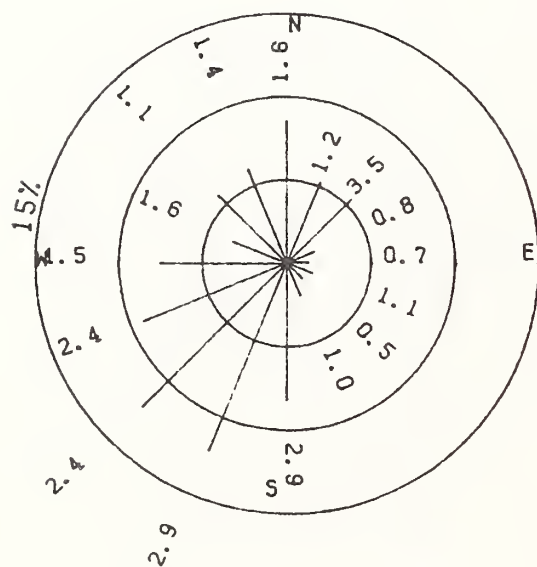
KALISPELL MONTANA



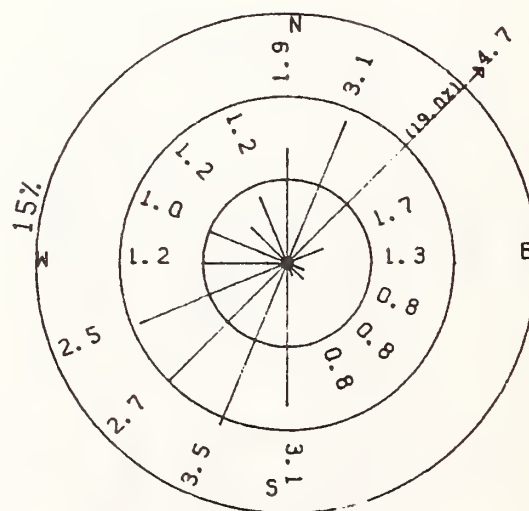
SEPTEMBER 1980
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 720)



OCTOBER 1980
HOURS 0 TO 23
CALM 2.1%
(TOTAL HOURS 713)



NOVEMBER 1980
HOURS 0 TO 23
CALM 8.5%
(TOTAL HOURS 560)

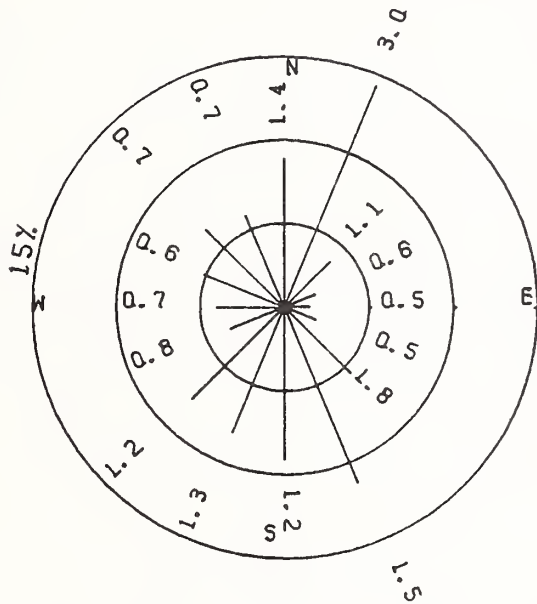


DECEMBER 1980
HOURS 0 TO 23
CALM 3.6%
(TOTAL HOURS 705)

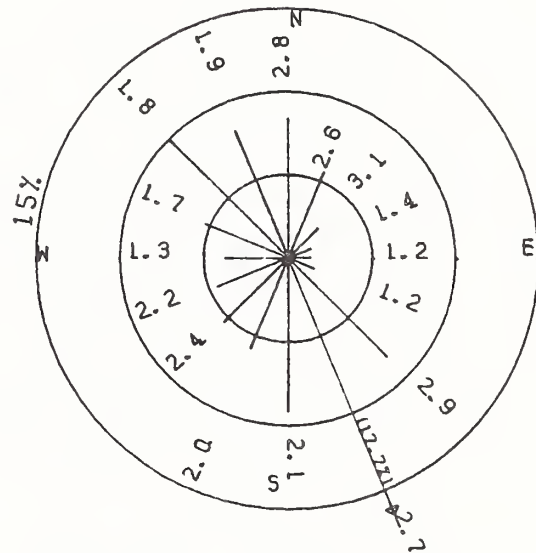
FIGURE 4-C

SURFACE WIND ROSES

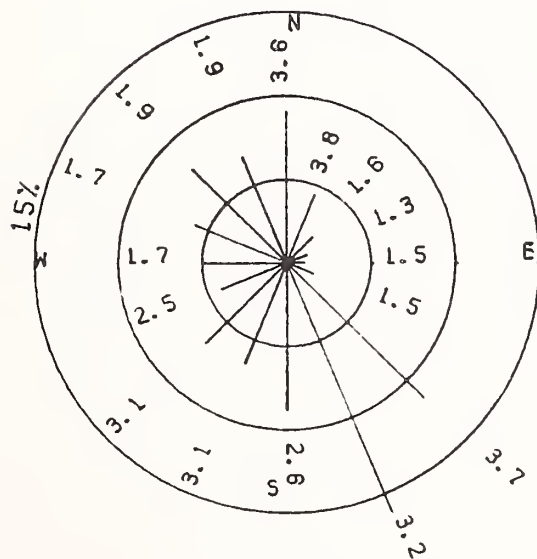
SITE: 480304 FLATHEAD AIRPORT (GIA) QUARTERLY
KALISPELL MONTANA



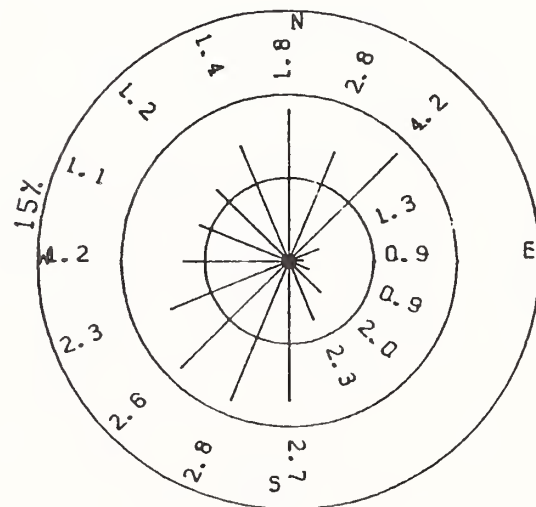
JANUARY - Mar 1980
HOURS 0 TO 23
CALM 0.9%
(TOTAL HOURS 2096)



APRIL - June 1980
HOURS 0 TO 23
CALM 1.0%
(TOTAL HOURS 1534)



JULY - Sept 1980
HOURS 0 TO 23
CALM 1.0%
(TOTAL HOURS 2186)



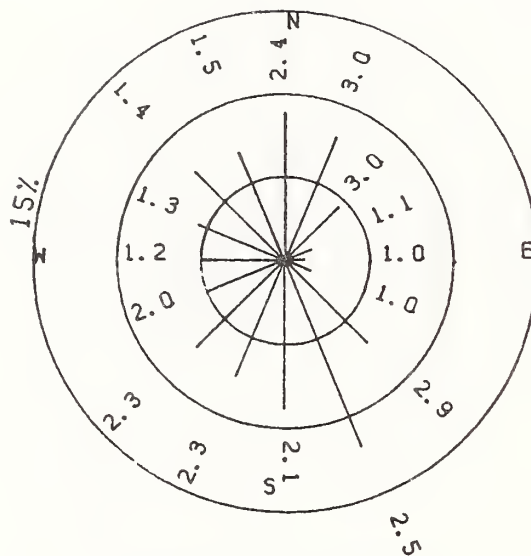
OCTOBER - Dec 1980
HOURS 0 TO 23
CALM 4.5%
(TOTAL HOURS 1978)

FIGURE 4-D

SURFACE WIND ROSES

SITE: 480304 FLATHEAD AIRPORT (GIA) ANNUAL

KALISPELL MONTANA



JANUARY - Dec 1980
HOURS 0 TO 23
CALM 1.9%
(TOTAL HOURS 7794)

FIGURE 4-E

SITE: 480304 FLATHEAD AIRPORT (GIA) MONTHLY

The diagram shows the following values for each age group segment:

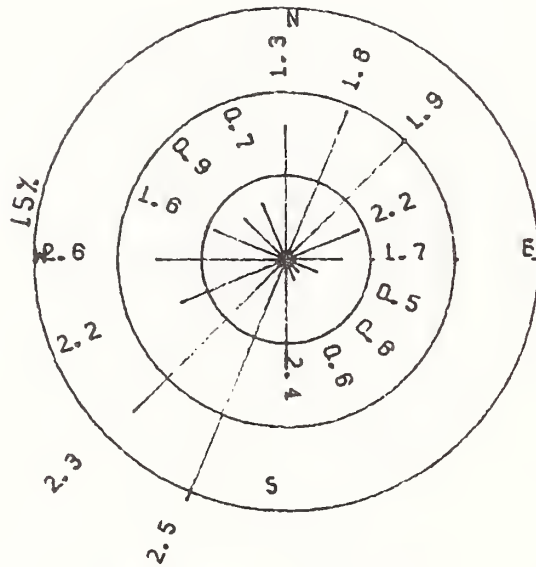
- 0-14: 15%
- 15-24: 9.7%
- 25-34: 2.1%
- 35-44: 2.0%
- 45-54: 1.3%
- 55-64: 1.3%
- 65-74: 1.3%
- 75+: 2.8%

67

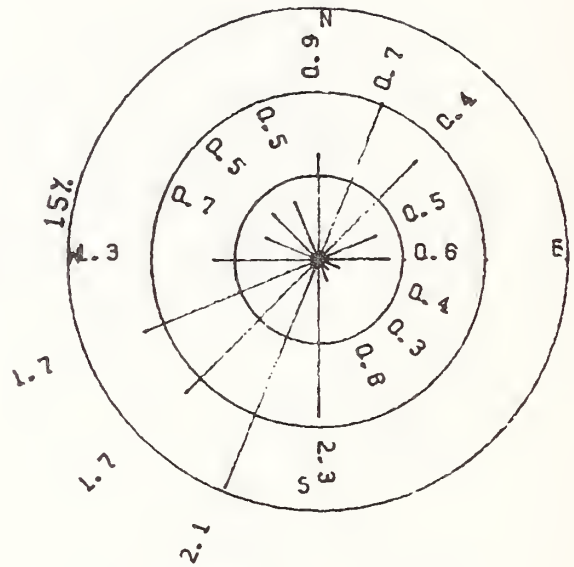
SURFACE WIND ROSES

SITE: 480304 FLATHEAD AIRPORT (GIA) MONTHLY

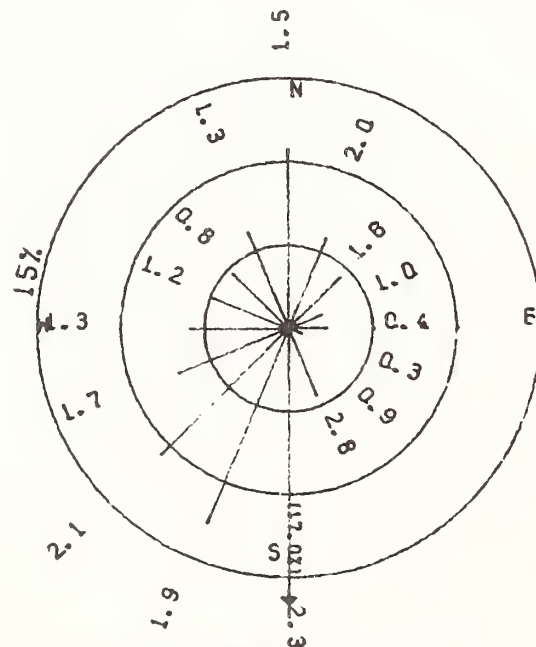
KALISPELL MONTANA



OCTOBER 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 744)



NOVEMBER 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 588)

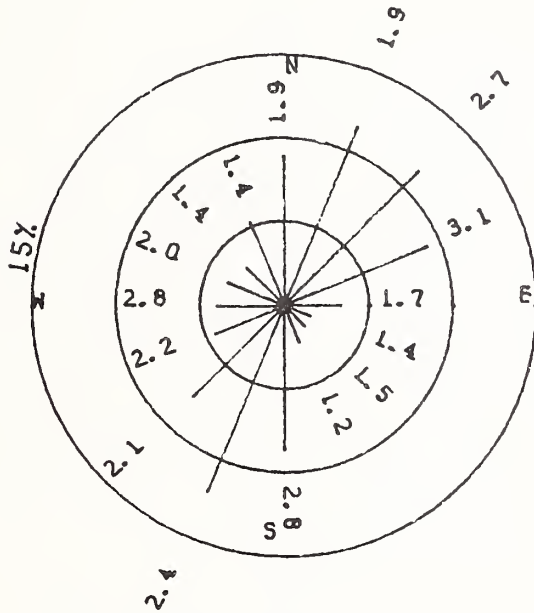


DECEMBER 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 683)

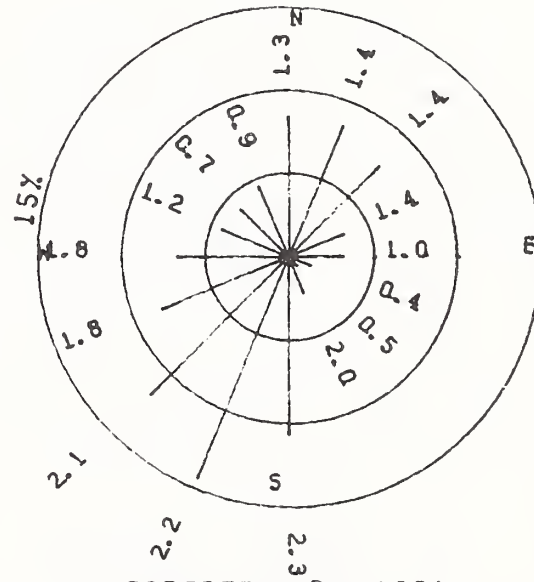
FIGURE 4-G

SURFACE WIND ROSES

SITE: 480304 FLATHEAD AIRPORT (GIA) QUARTERLY
KALISPELL MONTANA



JULY - Sept 1981
HOURS 0 TO 23
CALM 1.1%
(TOTAL HOURS 2141)



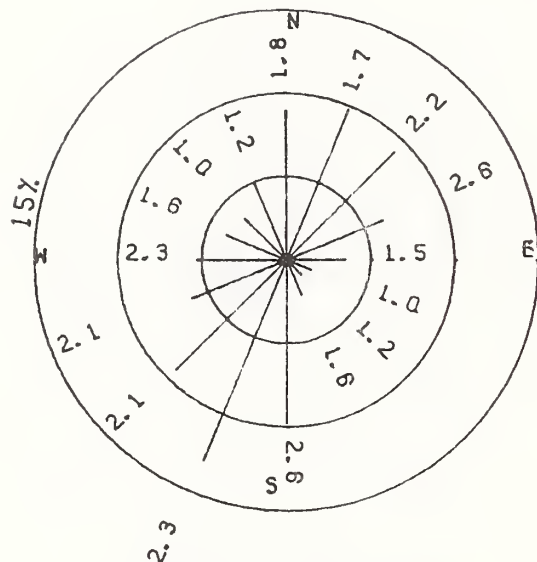
OCTOBER - Dec 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 2015)

FIGURE 4-H

SURFACE WIND ROSES

SITE: 480304 FLATHEAD AIRPORT (G1A) ANNUAL

KALISPELL MONTANA



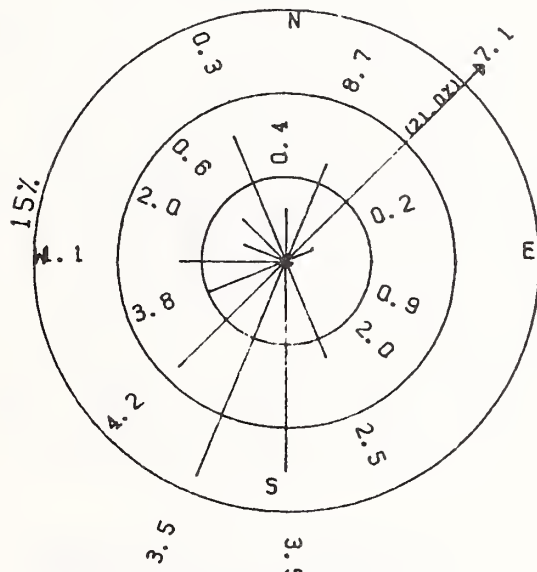
JANUARY - Dec 1981
HOURS 0 TO 23
CALM 1.5%
(TOTAL HOURS 4343)

FIGURE 4-I

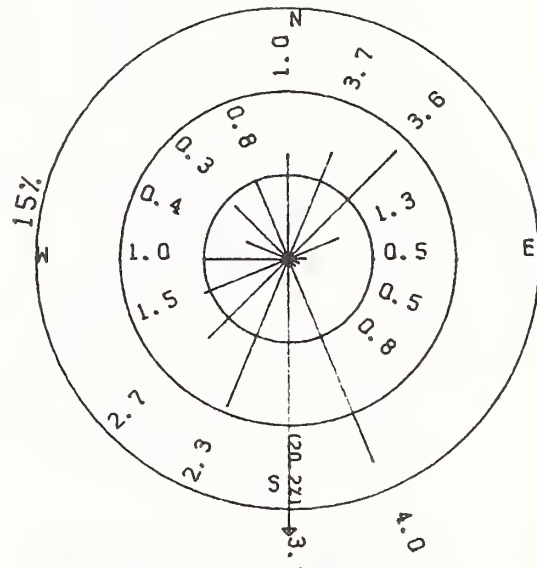
SURFACE WIND ROSES

SITE: 480304 FLATHEAD AIRPORT (GIA) MONTHLY

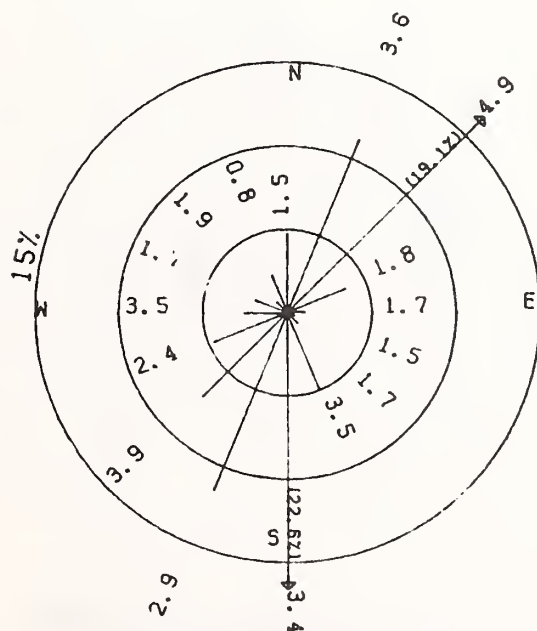
KALISPELL MONTANA



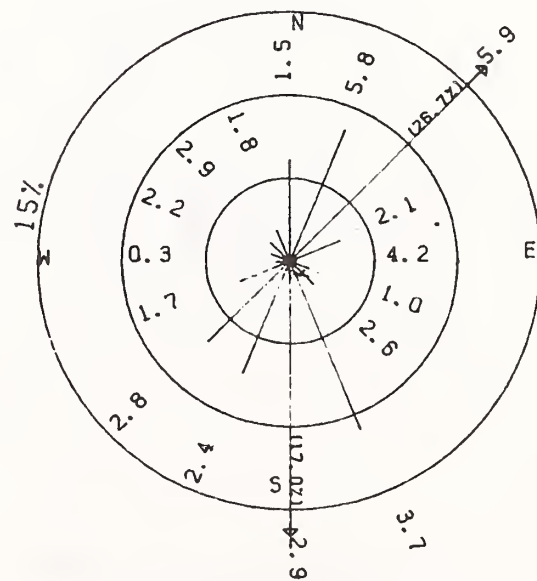
JANUARY 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 224)



FEBRUARY 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 672)



MARCH 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 744)



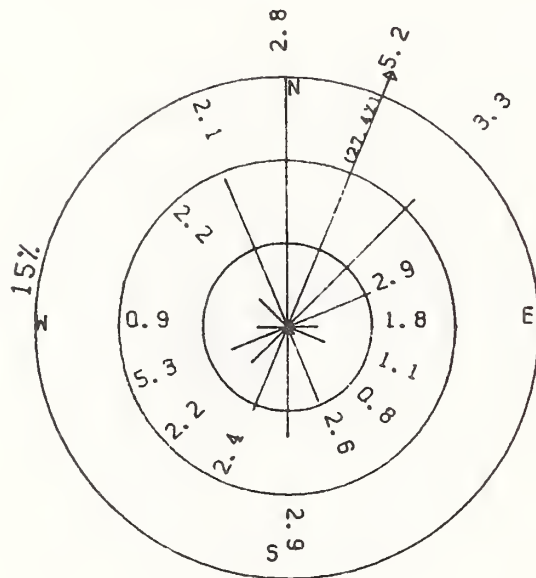
APRIL 1982
HOURS 0 TO 23
CALM 0.8%
(TOTAL HOURS 245)

FIGURE 4-J

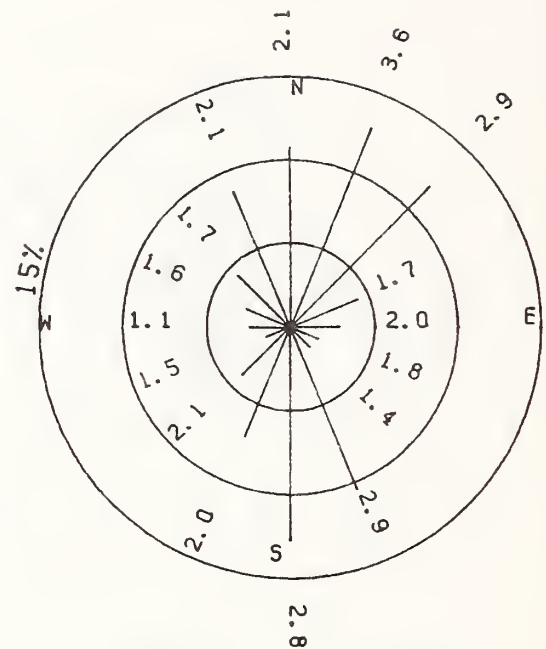
SURFACE WIND ROSES

SITE: 480304 FLATHEAD AIRPORT (GIA) MONTHLY

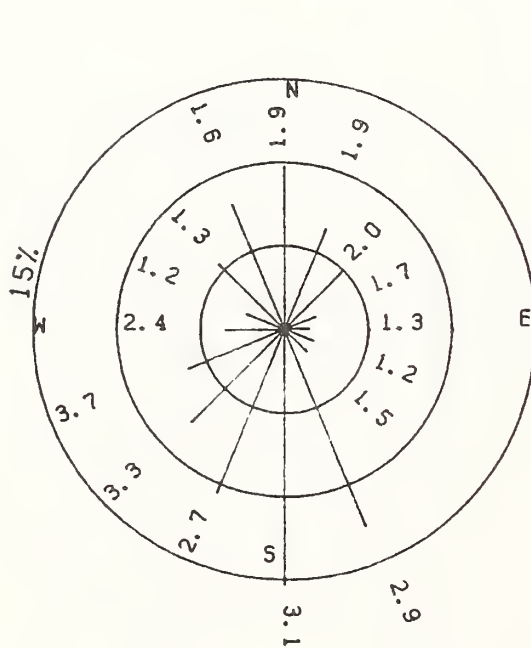
KALISPELL MONTANA



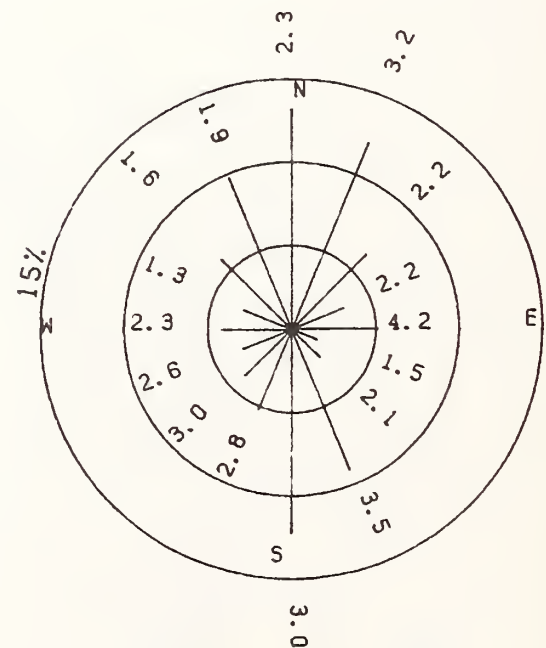
MAY 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 168)



JUNE 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 712)



JULY 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 744)



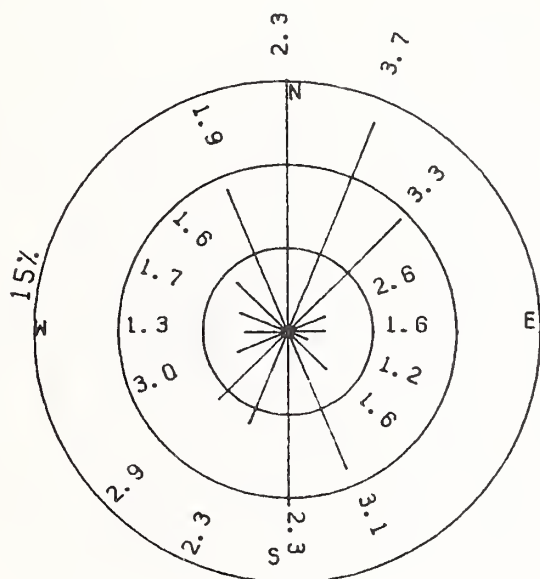
AUGUST 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 718)

FIGURE 4-K

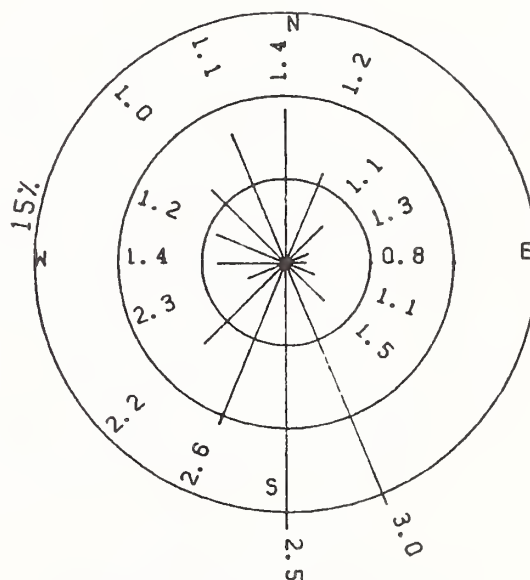
SURFACE WIND ROSES

SITE: 480304 FLATHEAD AIRPORT (GIA) MONTHLY

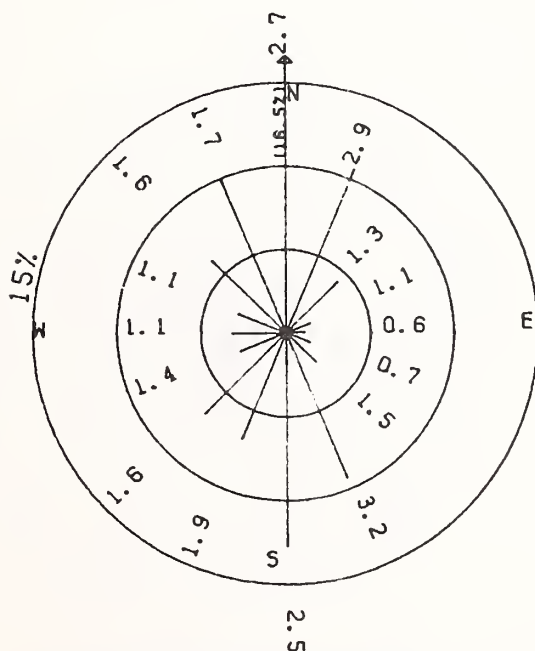
KALISPELL MONTANA



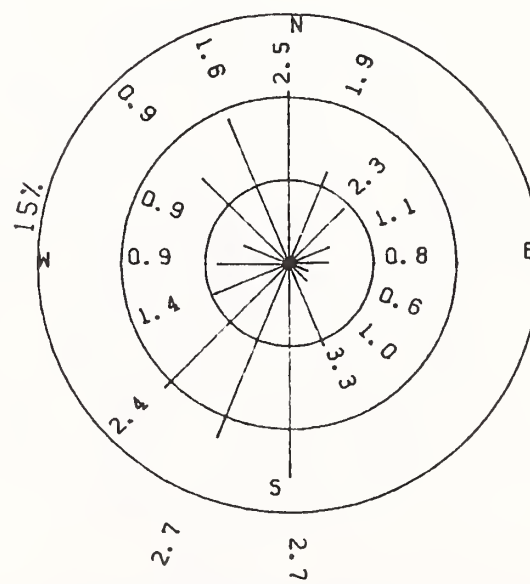
SEPTEMBER 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 720)



OCTOBER 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 744)



NOVEMBER 1982
HOURS 0 TO 23
CALM 1.2%
(TOTAL HOURS 711)

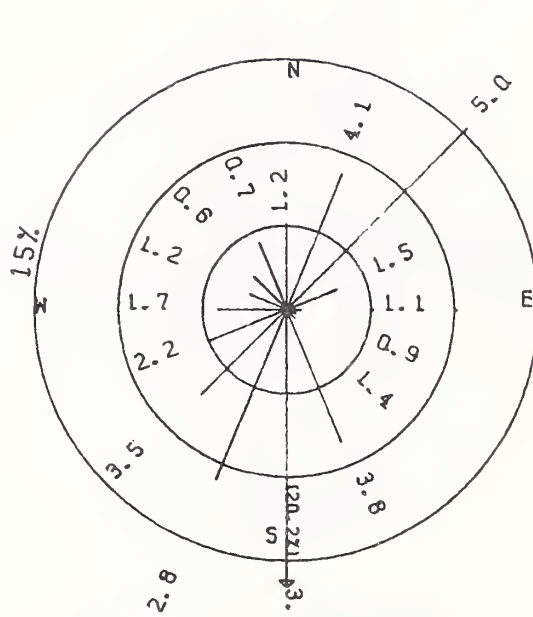


DECEMBER 1982
HOURS 0 TO 23
CALM 3.0%
(TOTAL HOURS 706)

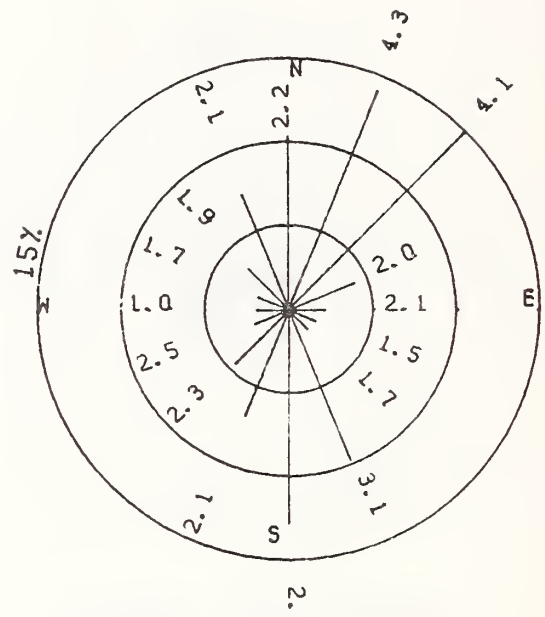
FIGURE 4-L

SURFACE WIND ROSES

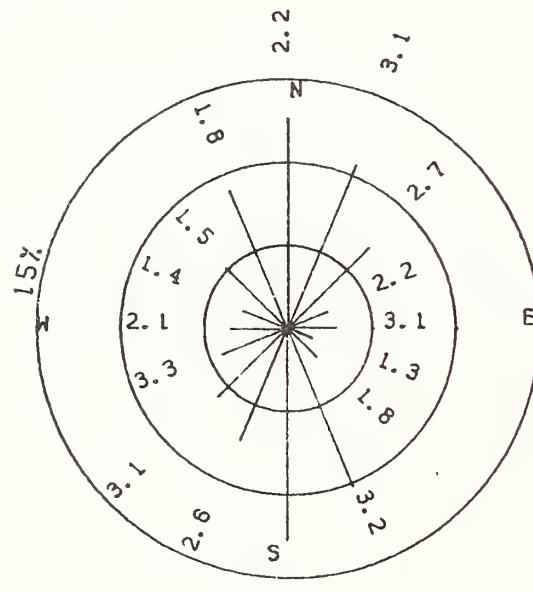
SITE: 480304 FLATHEAD AIRPORT (GIA) QUARTERLY
KALISPELL MONTANA



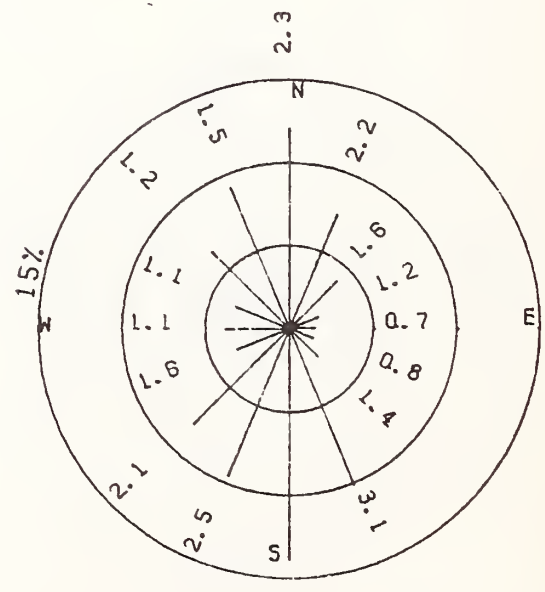
JANUARY - Mar 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 1640)



APRIL - June 1982
HOURS 0 TO 23
CALM 0.2%
(TOTAL HOURS 1125)



JULY - Sept 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 2182)



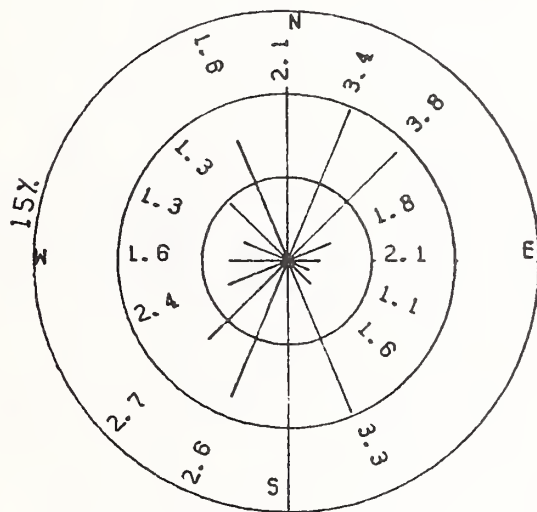
OCTOBER - Dec 1982
HOURS 0 TO 23
CALM 1.4%
(TOTAL HOURS 2161)

FIGURE 4-M

SURFACE WIND ROSES

SITE: 480304 FLATHEAD AIRPORT (GIA) ANNUAL

KALISPELL MONTANA



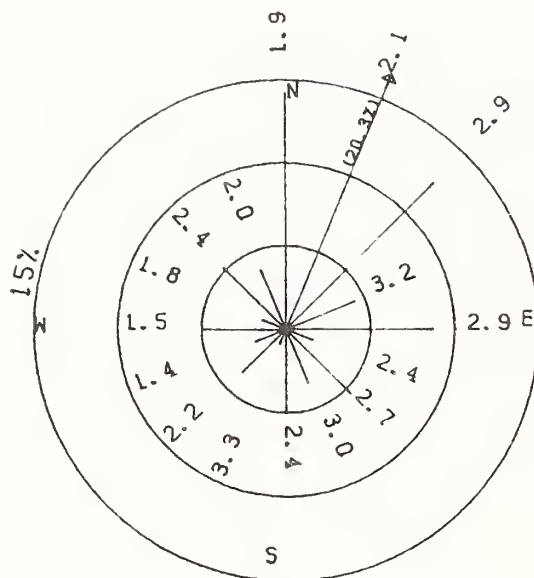
JANUARY - Dec 1982
HOURS 0 TO 23
CALM 0.5%
(TOTAL HOURS 7108)

FIGURE 4-N

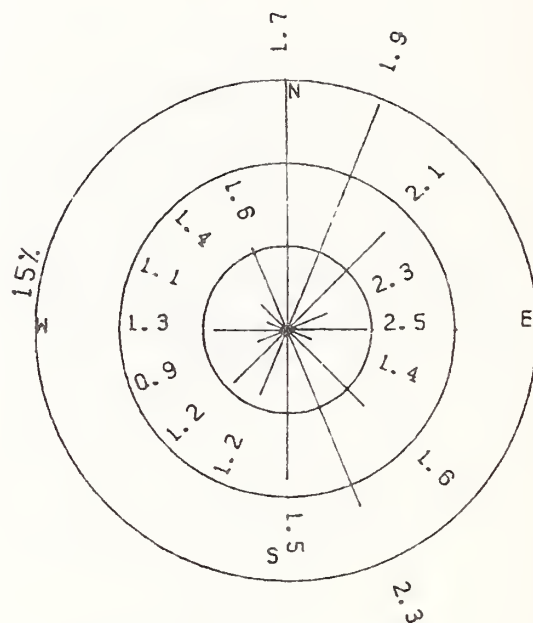
SURFACE WIND ROSES

SITE: 480036 BIGFORK-RANGER STATION MONTHLY

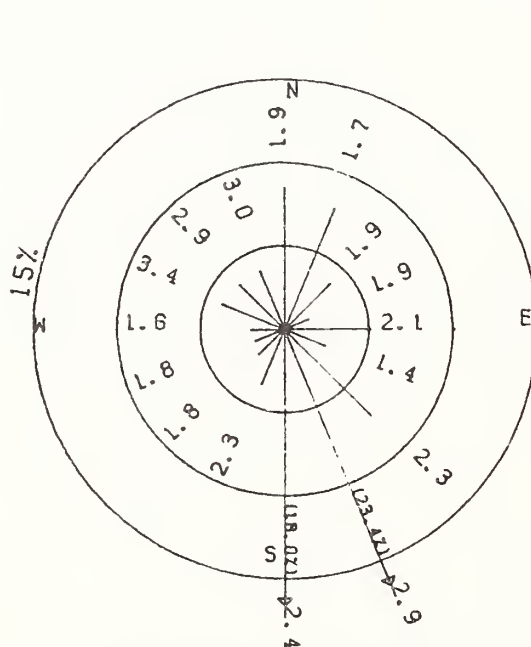
BIGFORK MONTANA



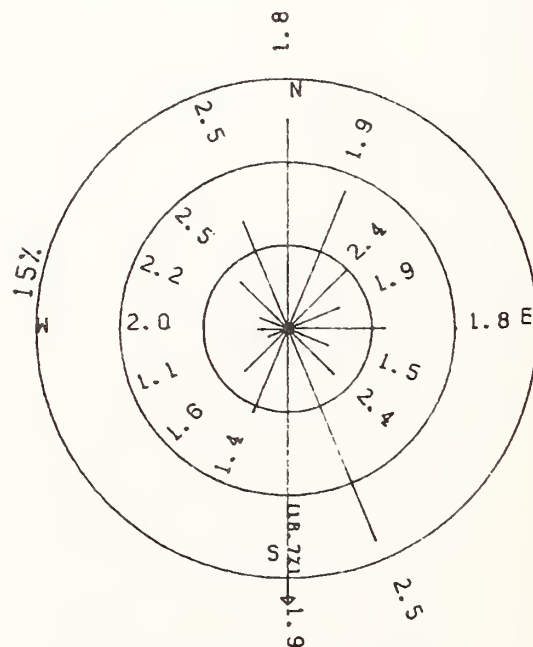
JANUARY 1980
HOURS 0 TO 23
CALM 2.3%
(TOTAL HOURS 505)



FEBRUARY 1980
HOURS 0 TO 23
CALM 3.2%
(TOTAL HOURS 674)



MARCH 1980
HOURS 0 TO 23
CALM 0.5%
(TOTAL HOURS 740)



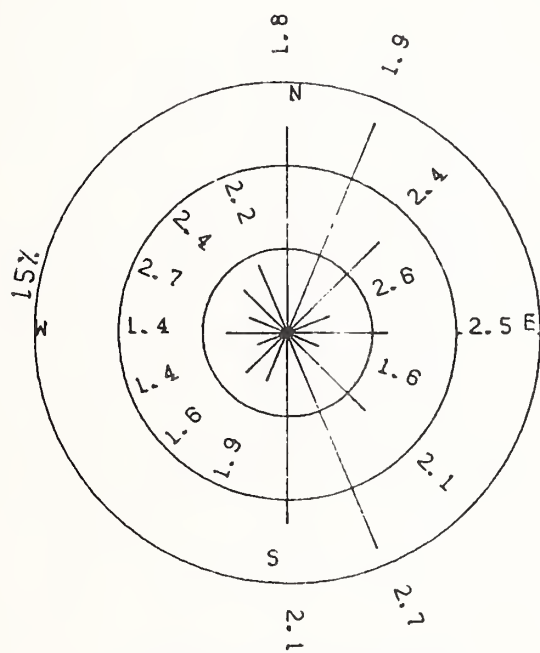
APRIL 1980
HOURS 0 TO 23
CALM 0.7%
(TOTAL HOURS 715)

FIGURE 5-A

SURFACE WIND ROSES

SITE: 480036 BIGFORK-RANGER STATION QUARTERLY

BIGFORK MONTANA



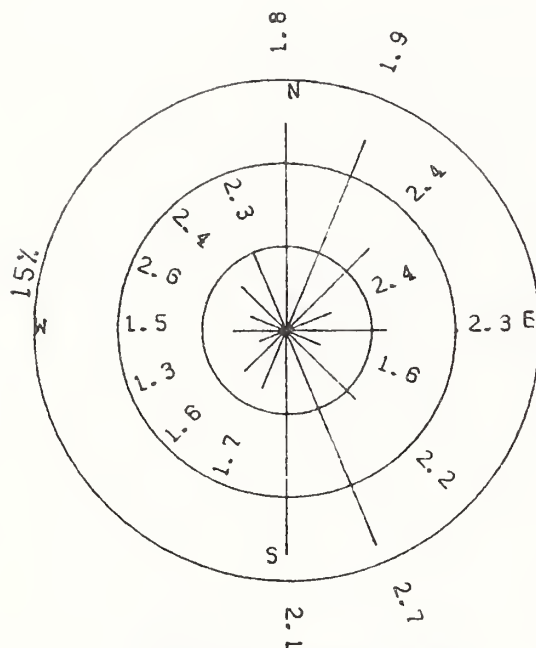
JANUARY - Mar 1980
HOURS 0 TO 23
CALM 1.9%
(TOTAL HOURS 1919)

FIGURE 5-B

SURFACE WIND ROSES

SITE: 480036 BIGFORK-RANGER STATION ANNUAL

BIGFORK MONTANA



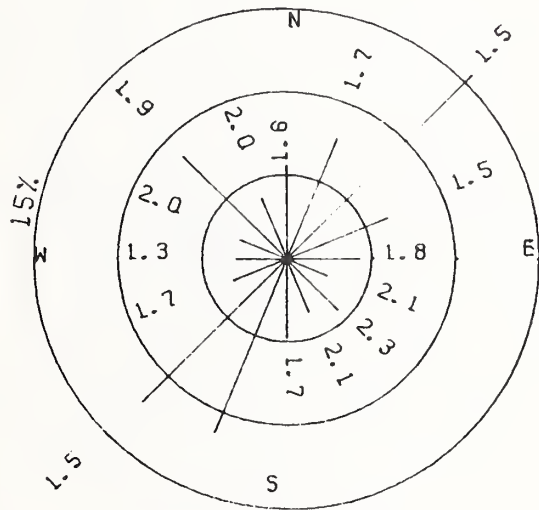
JANUARY - Apr 1980
HOURS 0 TO 23
CALM 1.6%
(TOTAL HOURS 2634)

FIGURE 5-C

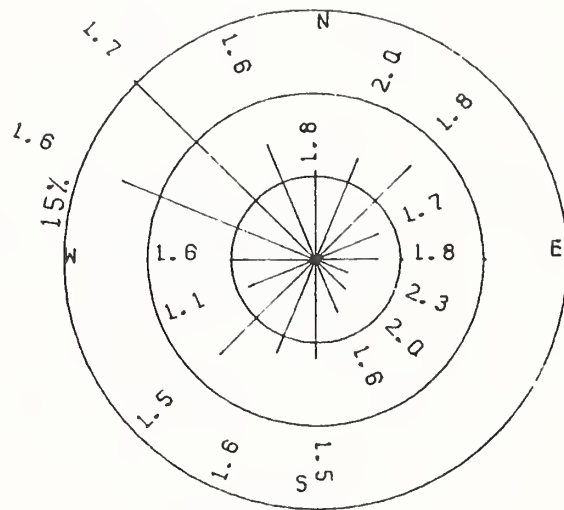
SURFACE WIND ROSES

SITE: 480036 BIGFORK-RANGER STATION MONTHLY

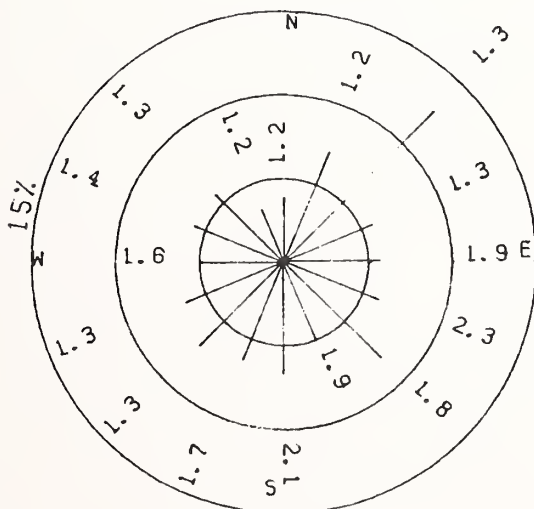
BIGFORK MONTANA



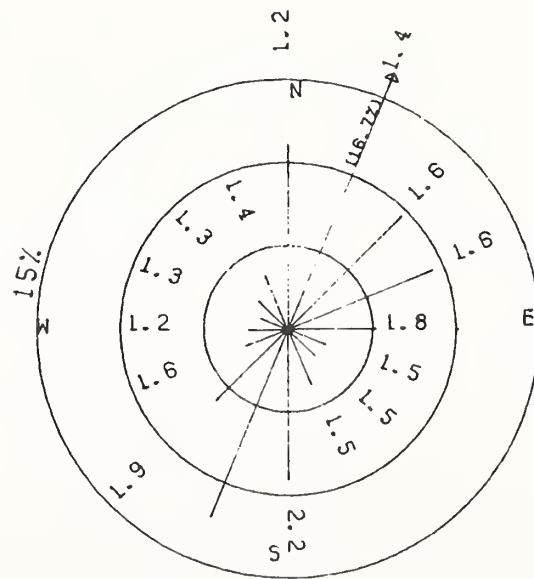
JULY 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 232)



AUGUST 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 673)



SEPTEMBER 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 526)



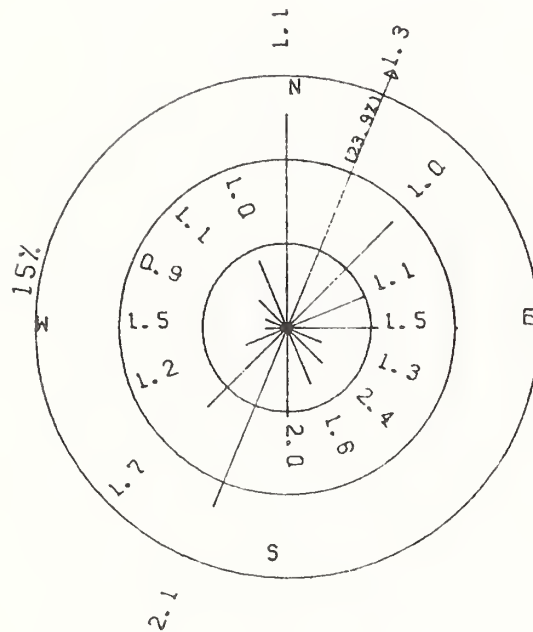
OCTOBER 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 743)

FIGURE 5-D

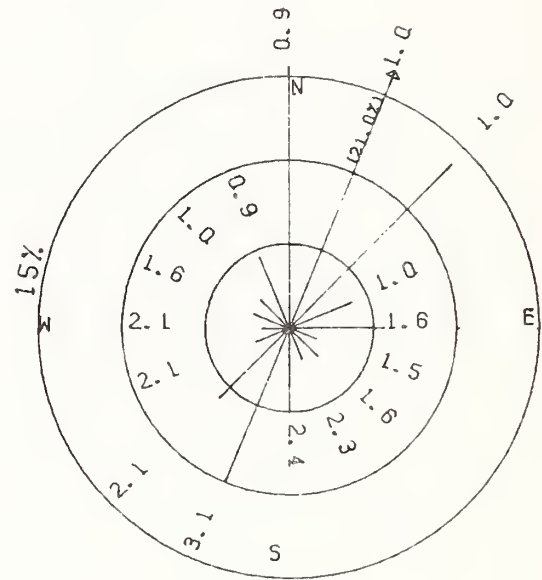
SURFACE WIND ROSES

SITE: 480036 BIGFORK-RANGER STATION MONTHLY

BIGFORK MONTANA



NOVEMBER 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 720)

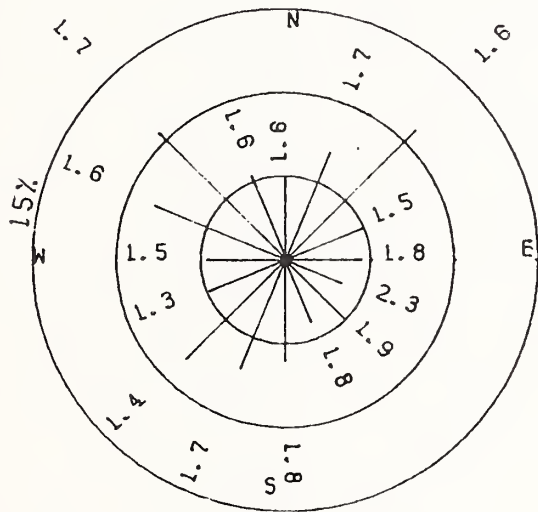


DECEMBER 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 744)

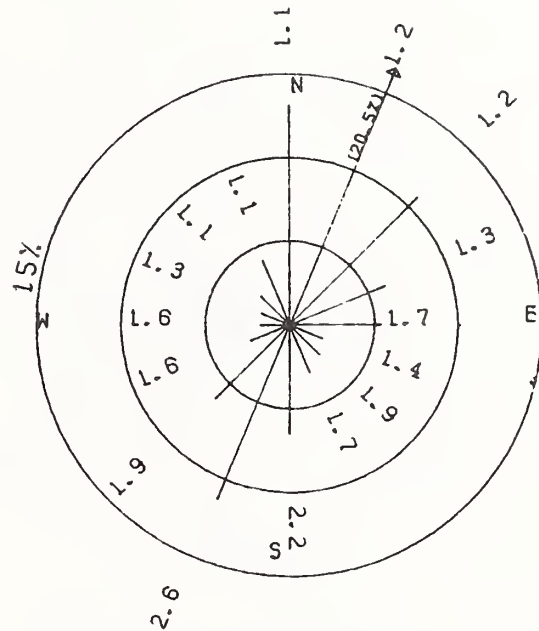
FIGURE 5-E

SURFACE WIND ROSES

SITE: 480036 BIGFORK-RANGER STATION QUARTERLY
BIGFORK MONTANA



JULY - Sept 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 1431)

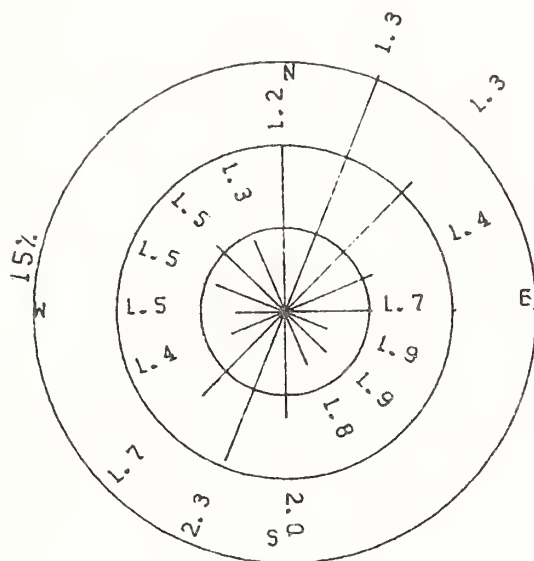


OCTOBER - Dec 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 2207)

FIGURE 5-F

SURFACE WIND ROSES

SITE: 480036 BIGFORK-RANGER STATION ANNUAL
BIGFORK MONTANA

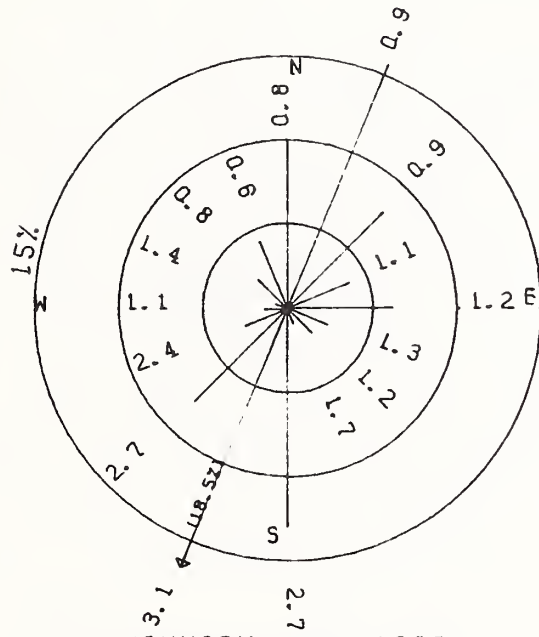


JULY - Dec 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 3638)

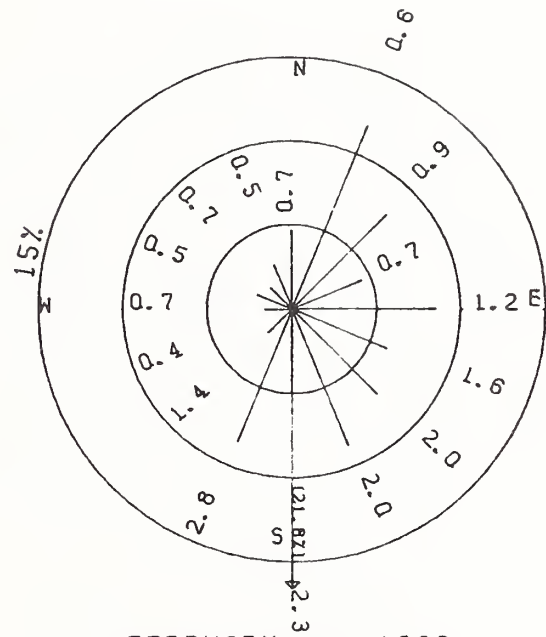
FIGURE 5-G

SURFACE WIND ROSES

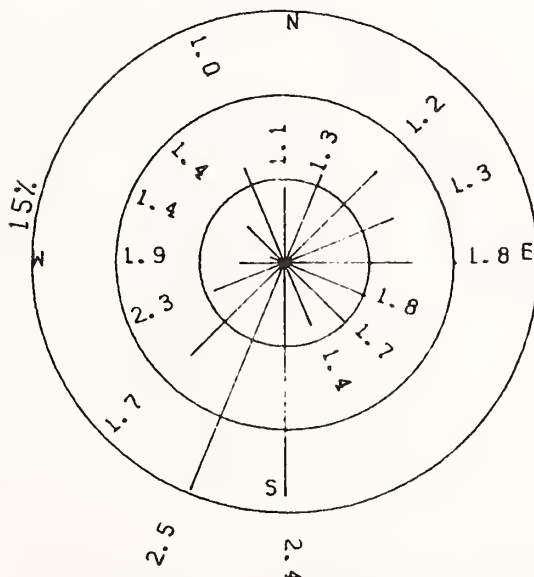
SITE: 480036 BIGFORK-RANGER STATION MONTHLY
BIGFORK MONTANA



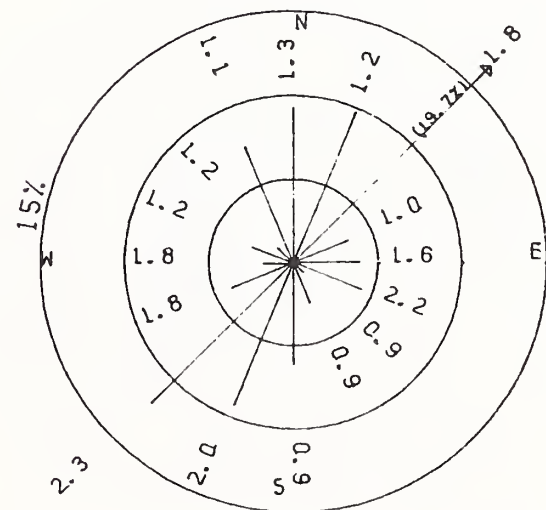
JANUARY 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 739)



FEBRUARY 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 495)



MARCH 1982
HOURS 0 TO 23
CALM 0.1%
(TOTAL HOURS 690)



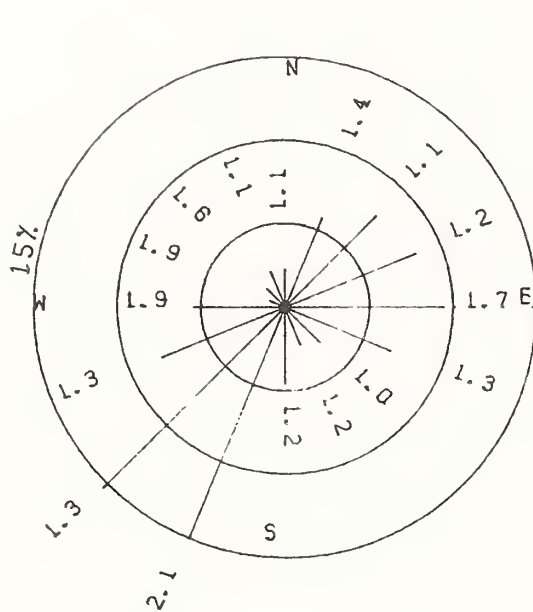
APRIL 1982
HOURS 0 TO 23
CALM 1.8%
(TOTAL HOURS 224)

FIGURE 5-H

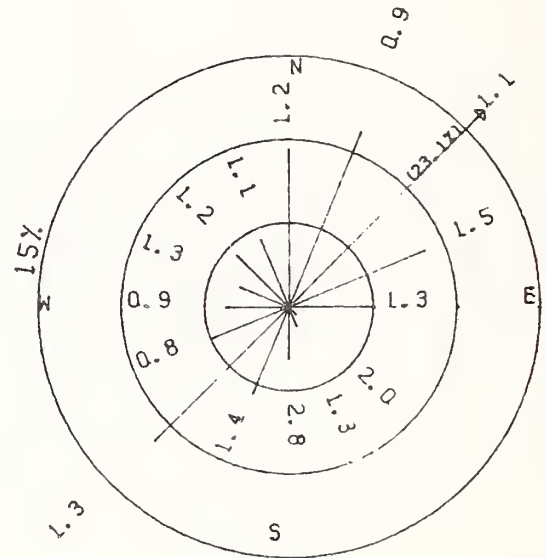
SURFACE WIND ROSES

SITE: 480036 BIGFORK-RANGER STATION MONTHLY

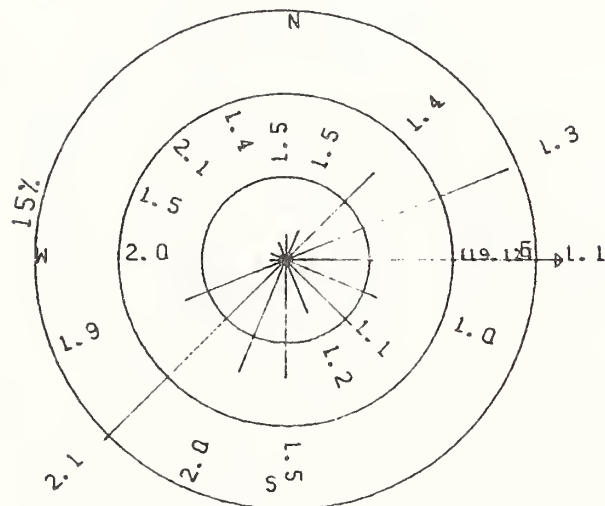
BIGFORK MONTANA



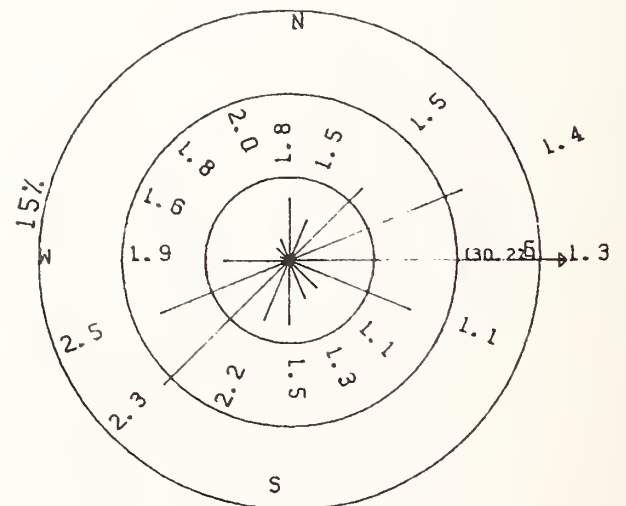
MAY 1982
HOURS 0 TO 23
CALM 1.1%
(TOTAL HOURS 564)



JUNE 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 160)



JULY 1982
HOURS 0 TO 23
CALM 1.3%
(TOTAL HOURS 517)

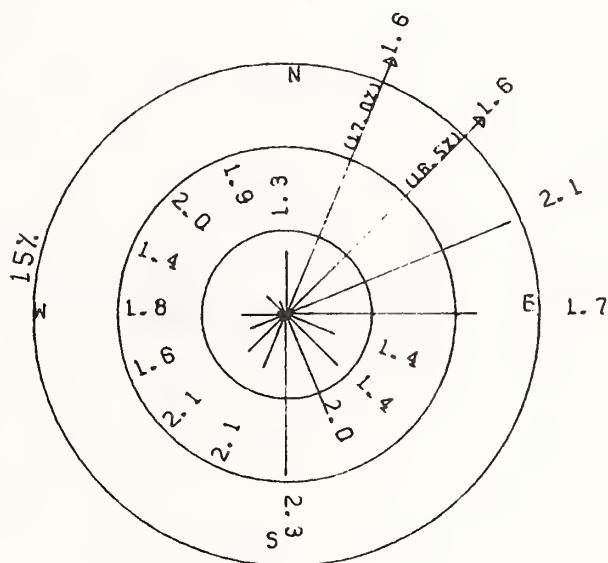


AUGUST 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 640)

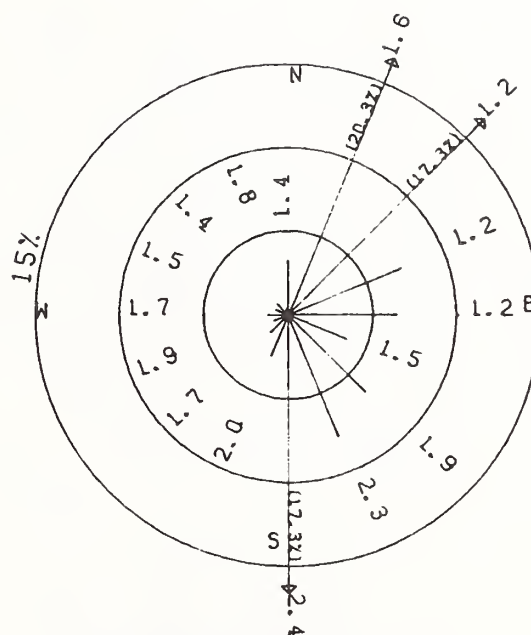
FIGURE 5-I

SURFACE WIND ROSES

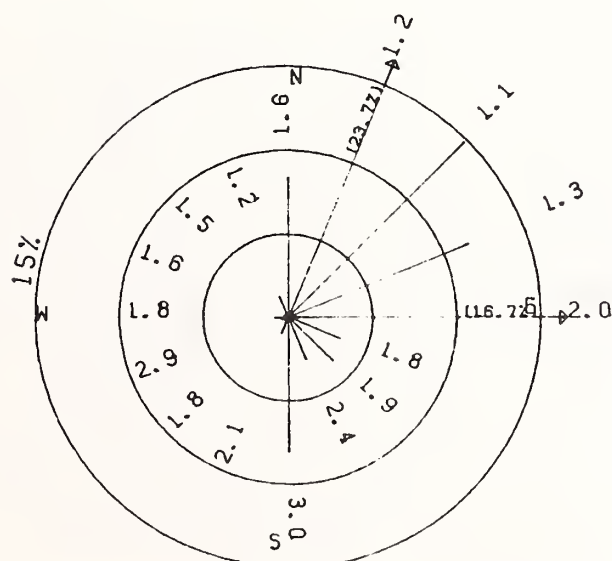
SITE: 480036 BIGFORK-RANGER STATION MONTHLY
BIGFORK MONTANA



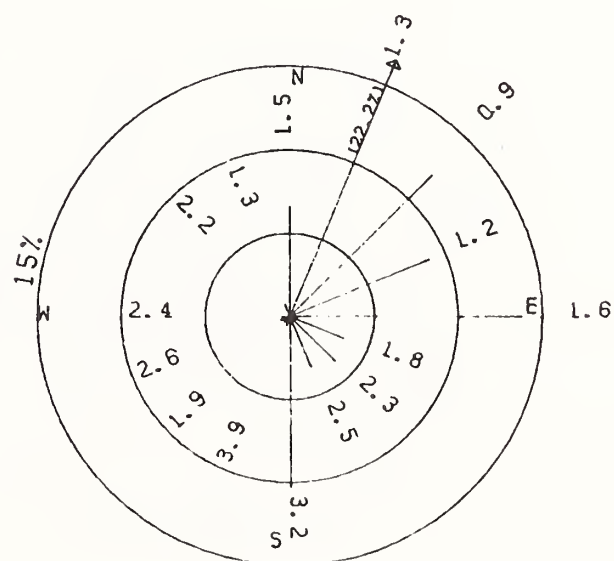
SEPTEMBER 1982
HOURS 0 TO 23
CALM 0.2%
(TOTAL HOURS 580)



OCTOBER 1982
HOURS 0 TO 23
CALM 1.6%
(TOTAL HOURS 732)



NOVEMBER 1982
HOURS 0 TO 23
CALM 2.5%
(TOTAL HOURS 702)



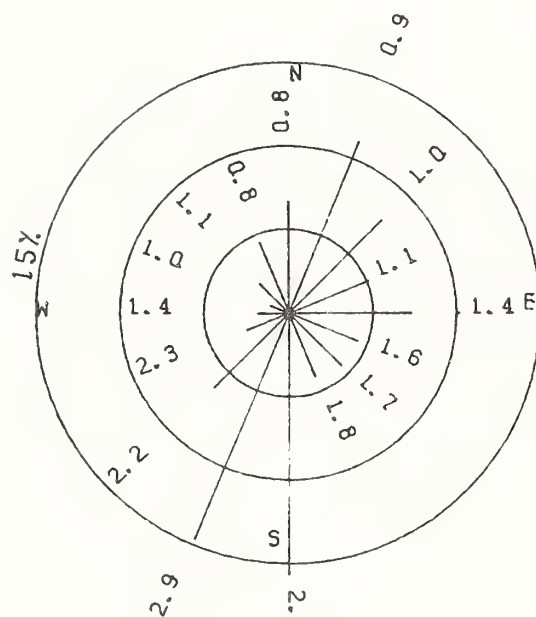
DECEMBER 1982
HOURS 0 TO 23
CALM 12.7%
(TOTAL HOURS 555)

FIGURE 5-J

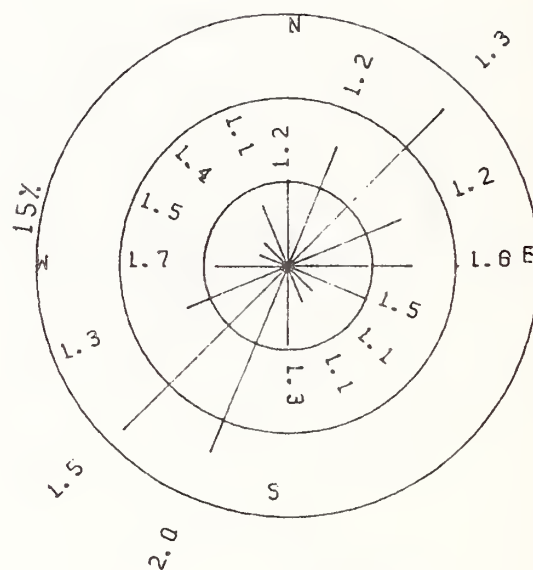
SURFACE WIND ROSES

SITE: 480036 BIGFORK-RANGER STATION QUARTERLY

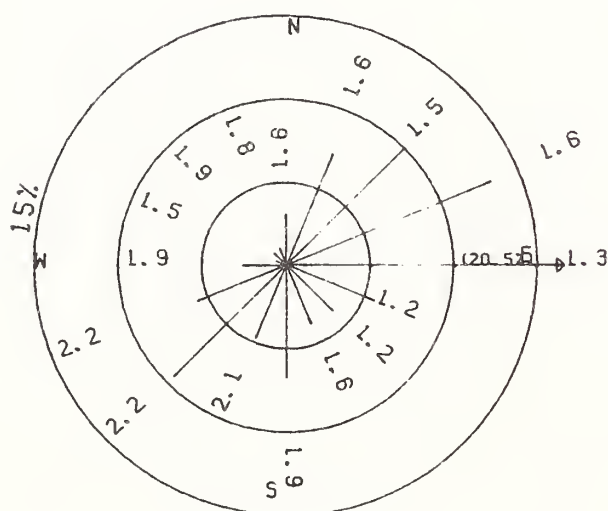
BIGFORK MONTANA



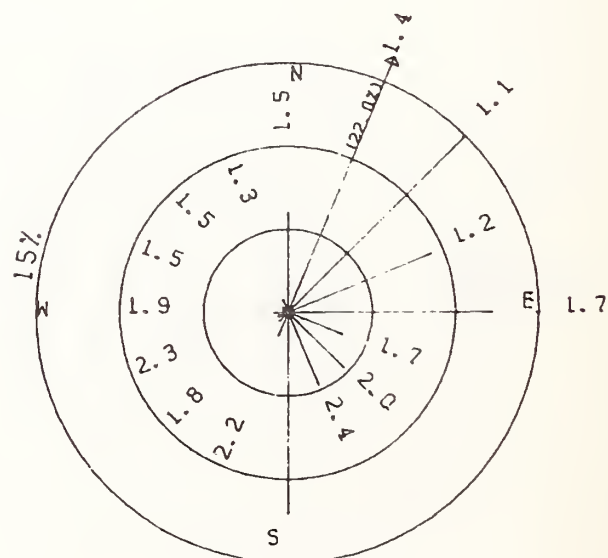
JANUARY - Mar 1982
HOURS 0 TO 23
CALM 0.1%
(TOTAL HOURS 1924)



APRIL - June 1982
HOURS 0 TO 23
CALM 1.0%
(TOTAL HOURS 948)



JULY - Sept 1982
HOURS 0 TO 23
CALM 0.5%
(TOTAL HOURS 1737)



OCTOBER - Dec 1982
HOURS 0 TO 23
CALM 5.3%
(TOTAL HOURS 1989)

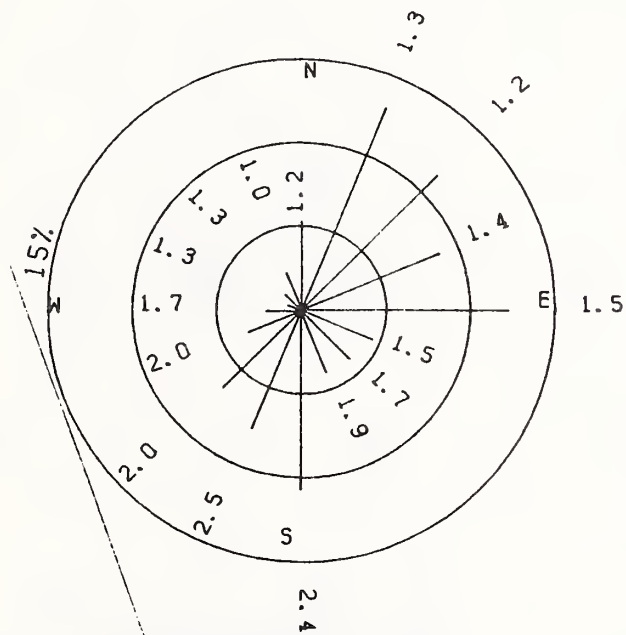
FIGURE 5-K.

SURFACE WIND ROSES

SITE: 480036 BIGFORK-RANGER STATION ANNUAL

BIGFORK

MONTANA



JANUARY - Dec 1982
HOURS 0 TO 23
CALM 1.9%
(TOTAL HOURS 6598)

FIGURE 5-L

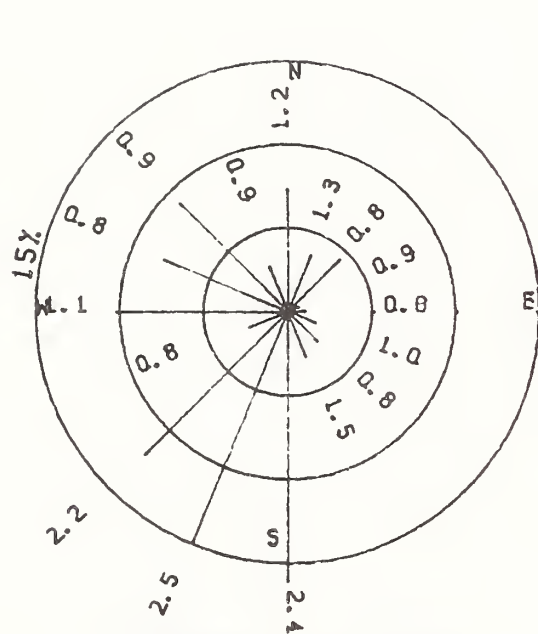
SURFACE WIND ROSES

SITE: 820010 POLSON (MAL)

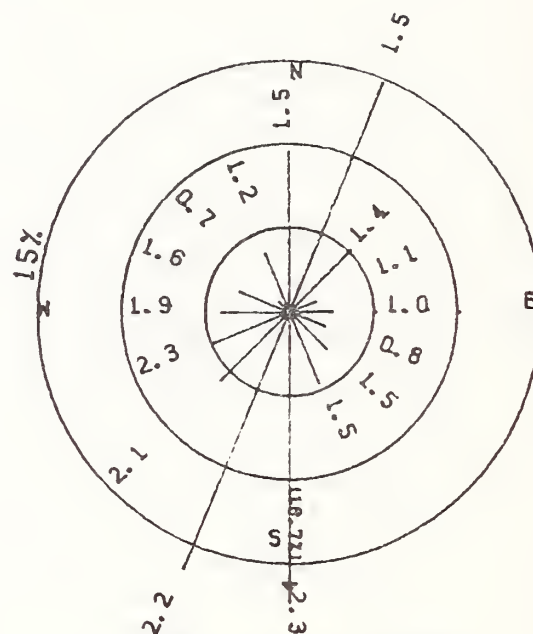
MONTHLY

POLSON

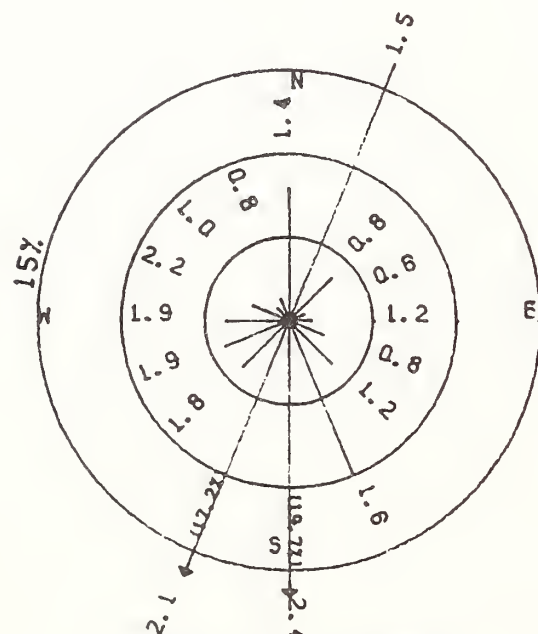
MONTANA



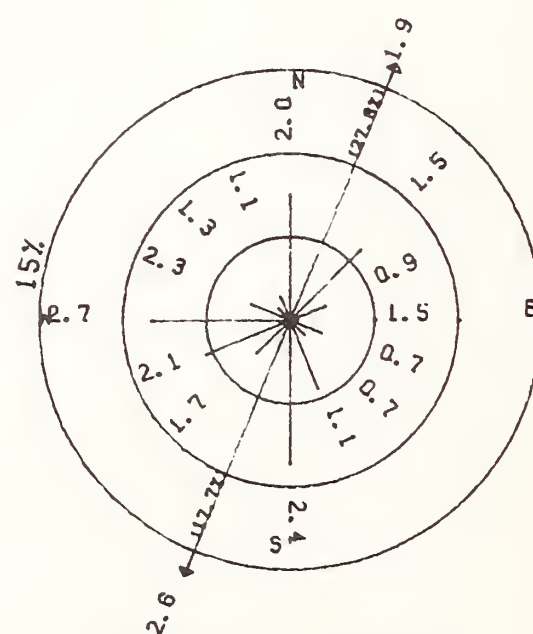
FEBRUARY 1980
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 275)



JUNE 1980
HOURS 0 TO 23
CALM 0.6%
(TOTAL HOURS 345)



JULY 1980
HOURS 0 TO 23
CALM 0.5%
(TOTAL HOURS 580)



AUGUST 1980
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 385)

FIGURE 6-A

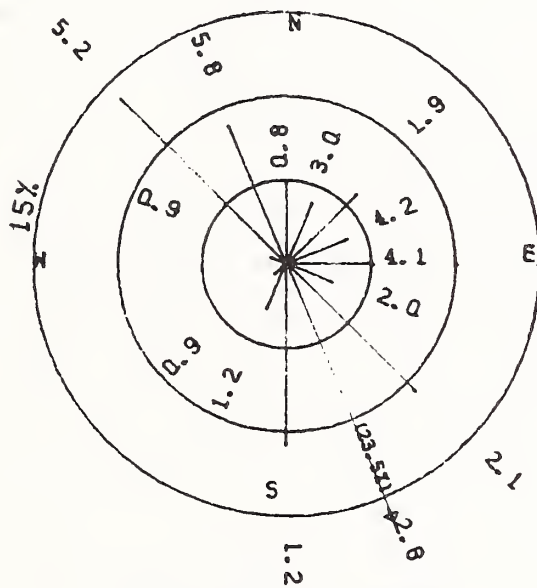
SURFACE WIND ROSES

SITE: 820010 POLSON (MAL)

MONTHLY

POLSON

MONTANA



SEPTEMBER 1980
HOURS 0 TO 23
CALM 1.0%
(TOTAL HOURS 101)

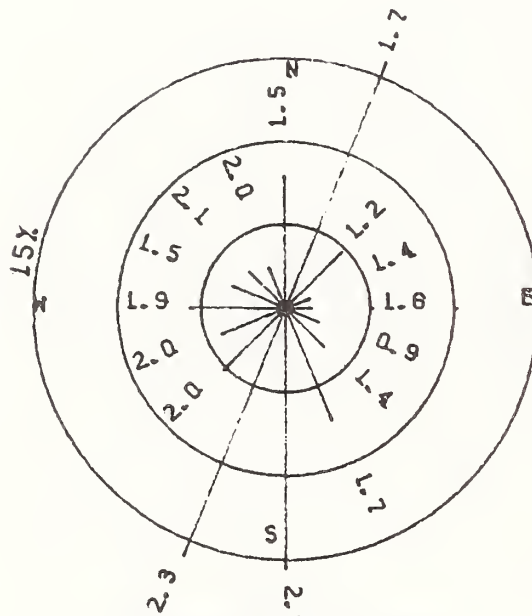
FIGURE 6-B

SURFACE WIND ROSES

SITE: 820010 POLSON (MAL) ANNUAL

POLSON

MONTANA



FEBRUARY-Sept 1980
HOURS 0 TO 23
CALM 0.4%
(TOTAL HOURS 1686)

FIGURE 6-C

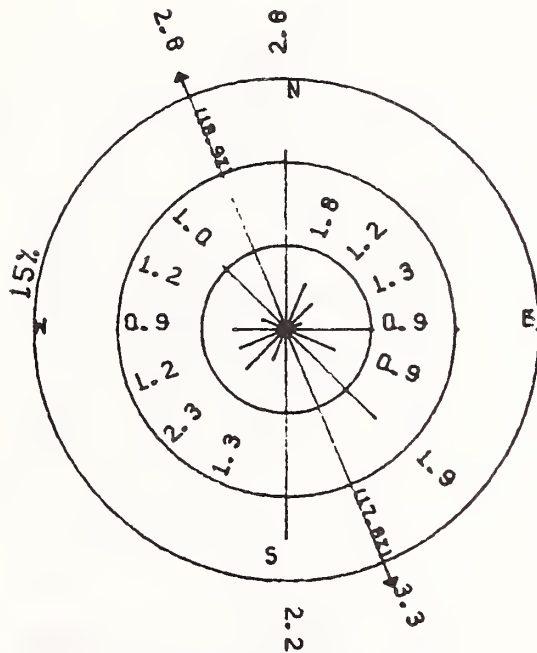
SURFACE WIND ROSES

SITE: 820010 POLSON (MAL)

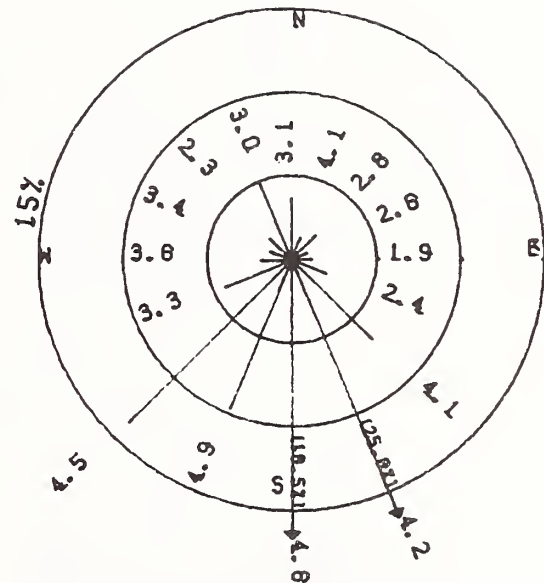
MONTHLY

POLSON

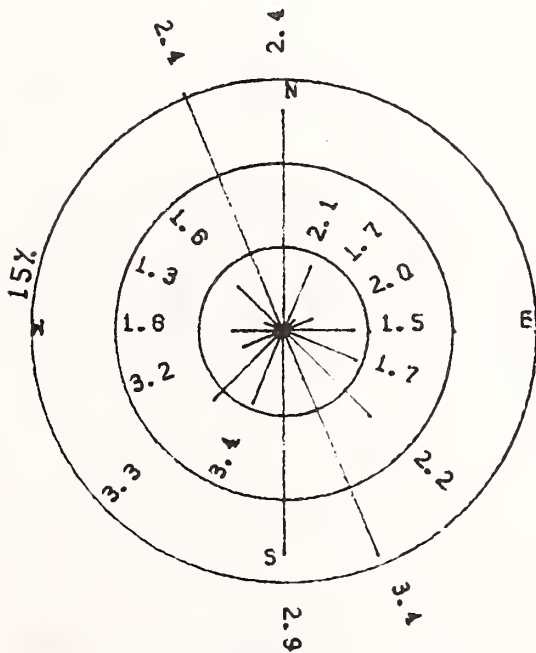
MONTANA



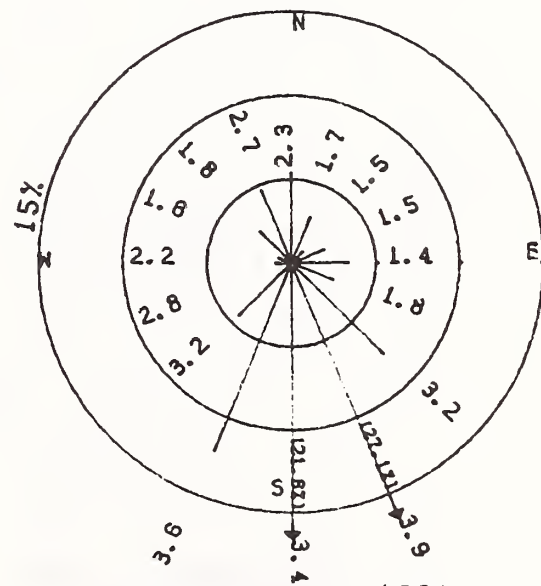
MARCH 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 507)



APRIL 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 492)



MAY 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 429)



JUNE 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 704)

FIGURE 6-D

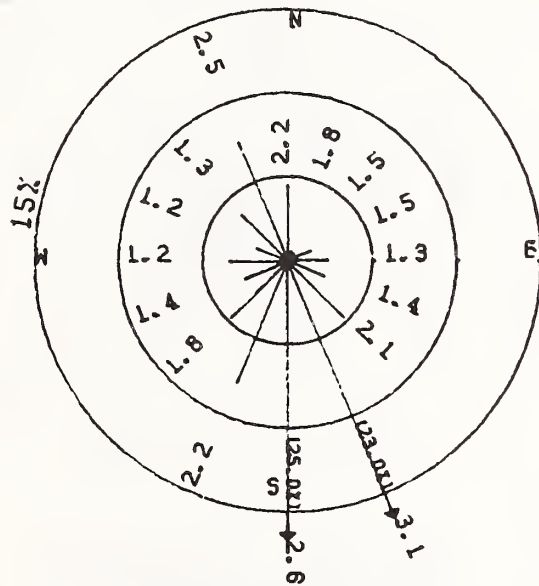
SURFACE WIND ROSES

SITE: 820010 POLSON (MAL)

MONTHLY

POLSON

MONTANA



NOVEMBER 1981
HOURS 0 TO 23
CALM 3.0%
(TOTAL HOURS 675)

FIGURE 6-F

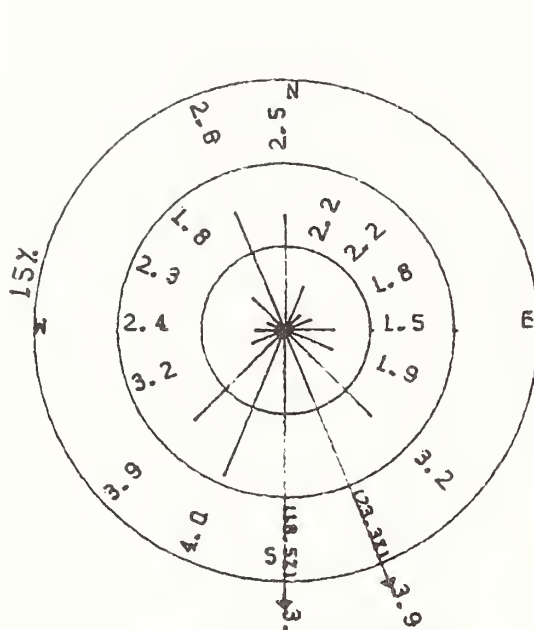
SURFACE WIND ROSES

SITE: 820010 POLSON (MAL)

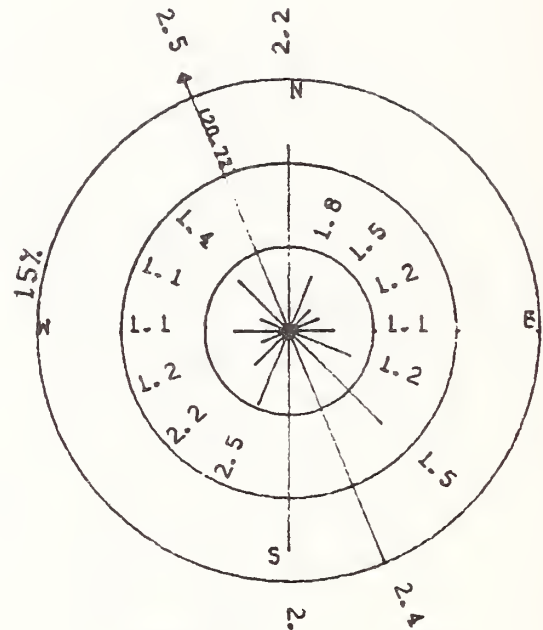
Quarterly

POLSON

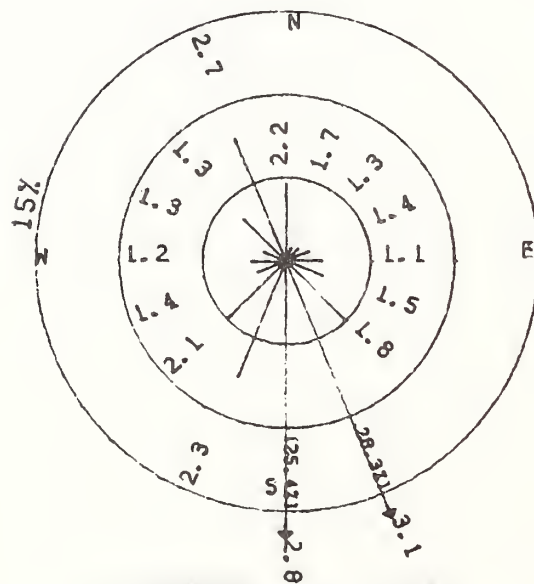
MONTANA



APRIL - June 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 1625)



JULY - Sept 1981
HOURS 0 TO 23
CALM 0.1%
(TOTAL HOURS 1819)



OCTOBER - Dec 1981
HOURS 0 TO 23
CALM 1.6%
(TOTAL HOURS 1308)

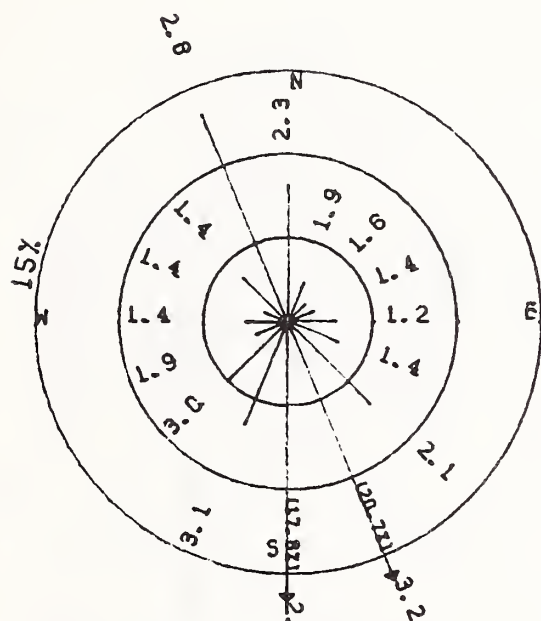
FIGURE 6-G

SURFACE WIND ROSES

SITE: 820010 POLSON (MAL) ANNUAL

POLSON

MONTANA



MARCH - NOV 1981
HOURS 0 TO 23
CALM 0.4%
(TOTAL HOURS 5259)

FIGURE 6-H

SURFACE WIND ROSES

SITE: 820010 POLSON (MAL)

MONTHLY

POLSON

MONTANA

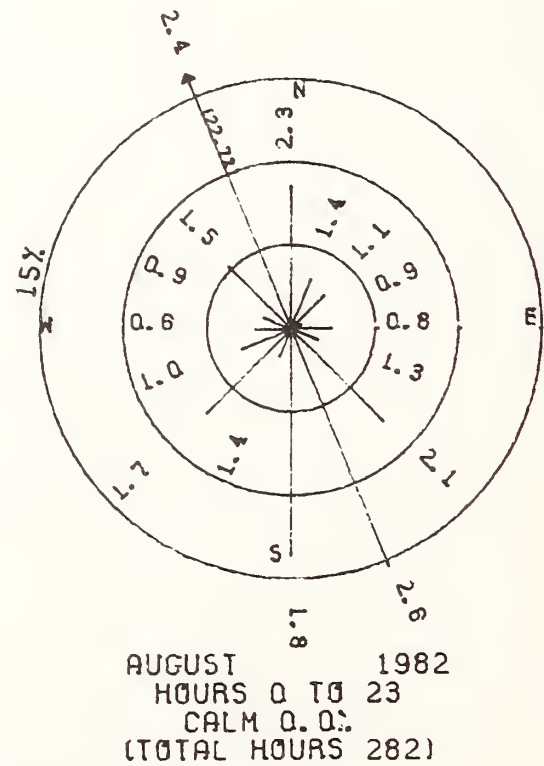
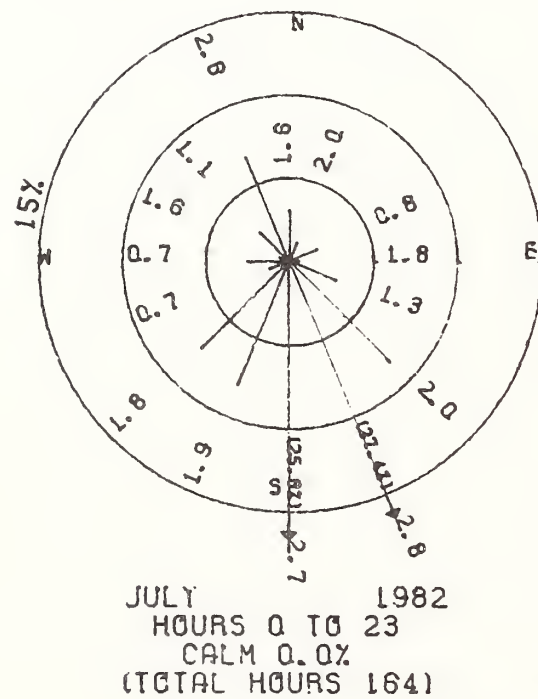
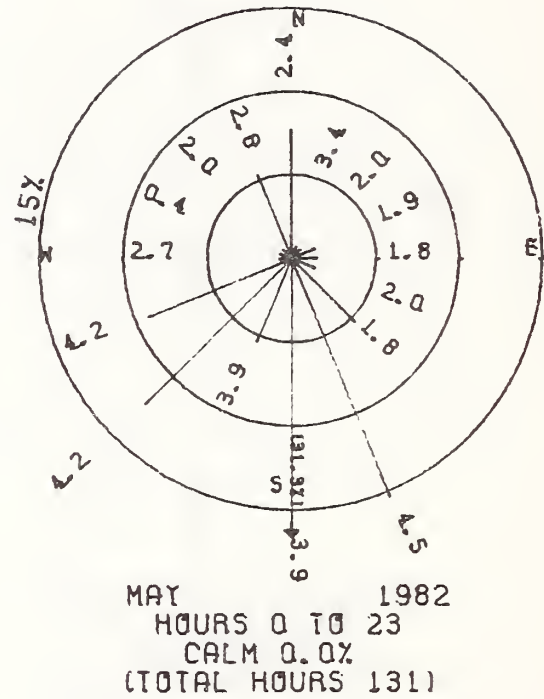
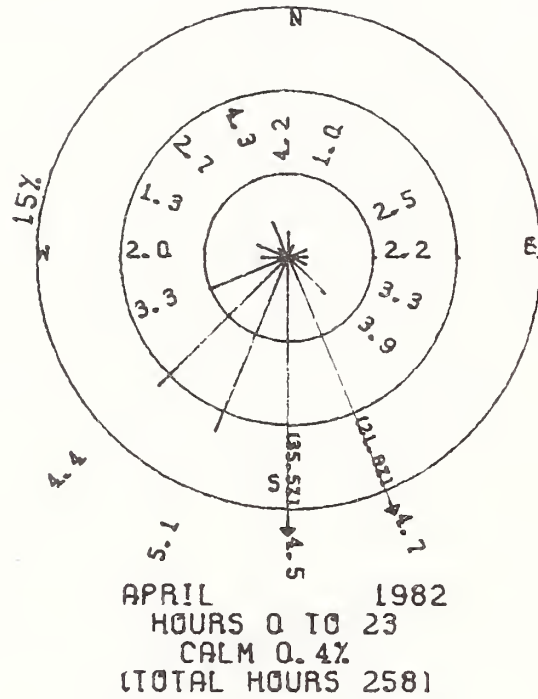


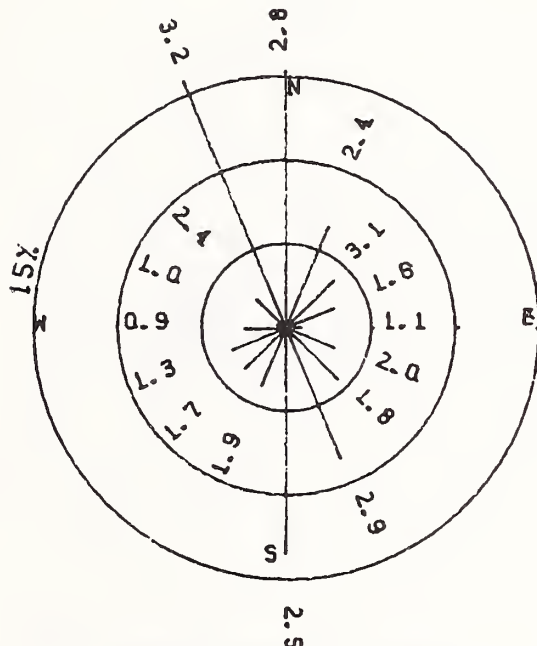
FIGURE 6-I

SURFACE WIND ROSES

SITE: 820010 POLSON (MAL) MONTHLY

POLSON

MONTANA



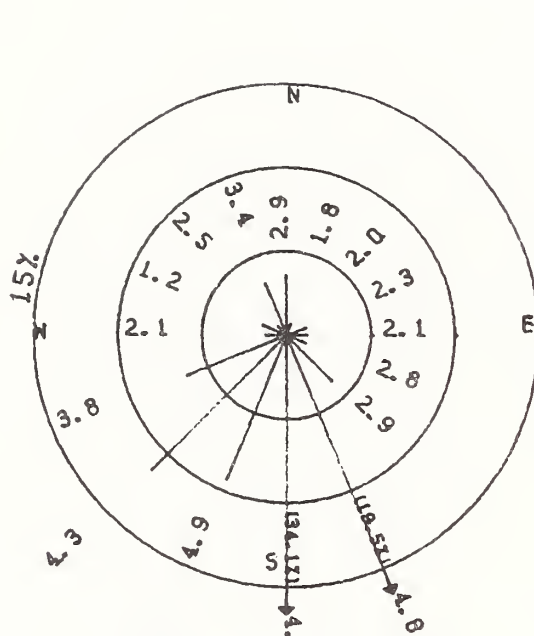
SURFACE WIND ROSES

SITE: 820010 POLSON (MAL)

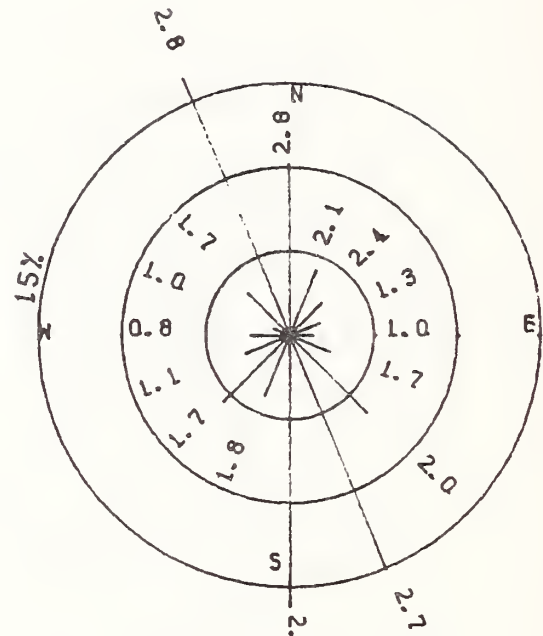
QUARTERLY

POLSON

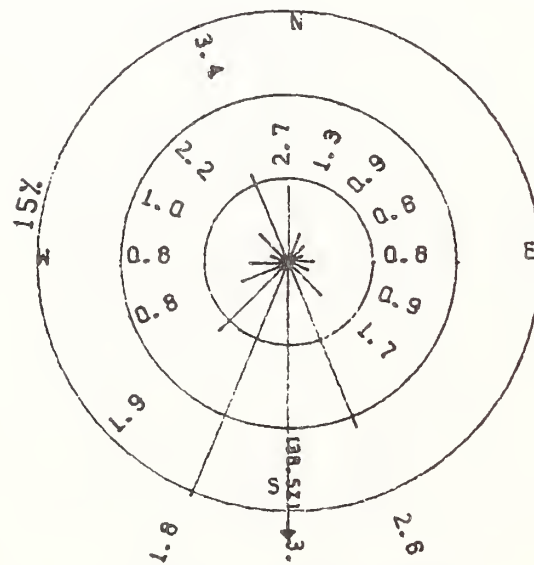
MONTANA



APRIL - June 1982
HOURS 0 TO 23
CALM 0.3%
(TOTAL HOURS 389)



JULY - Sept 1982
HOURS 0 TO 23
CALM 3.8%
(TOTAL HOURS 739)



OCTOBER - Dec 1982
HOURS 0 TO 23
CALM 1.3%
(TOTAL HOURS 1645)

FIGURE 6-K

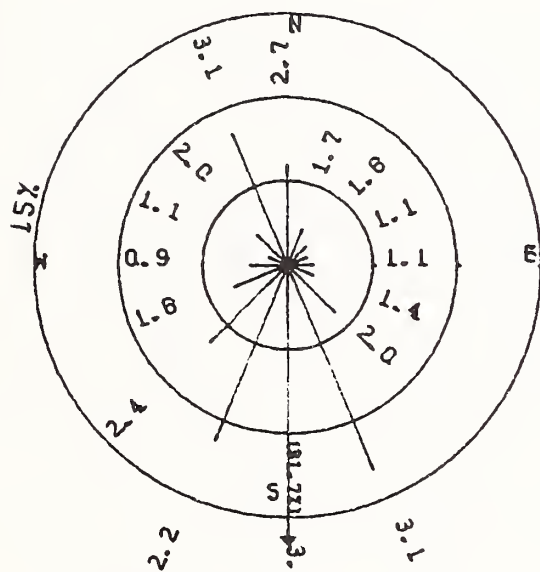
SURFACE WIND ROSES

SITE: 820010 POLSON (MAL)

ANNUAL

POLSON

MONTANA



MARCH - Dec 1982
HOURS 0 TO 23
CALM 1.8%
(TOTAL HOURS 2781)

FIGURE 6-L

SURFACE WIND ROSES

SITE: 820012 RONAN-NINEPIPES

MONTHLY

RONAN

MONTANA

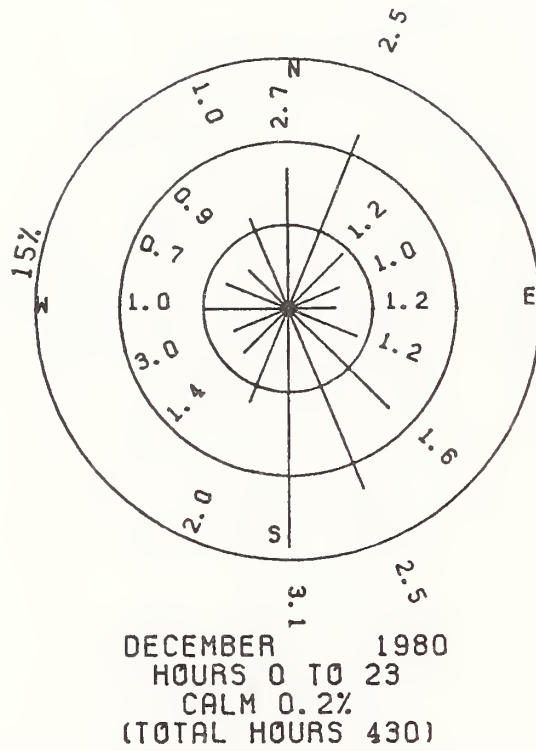


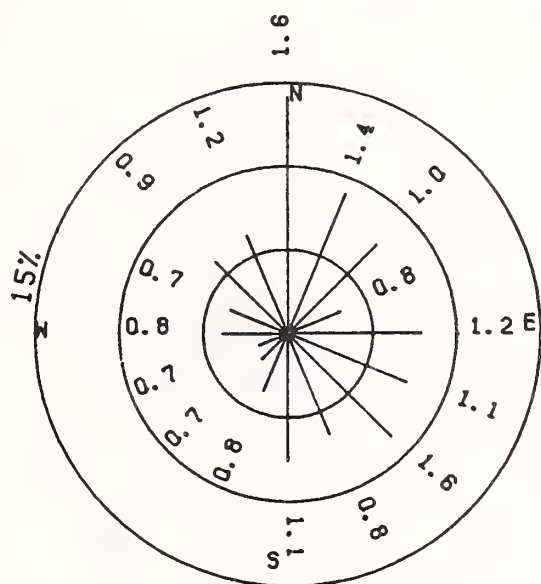
FIGURE 7-A

SURFACE WIND ROSES

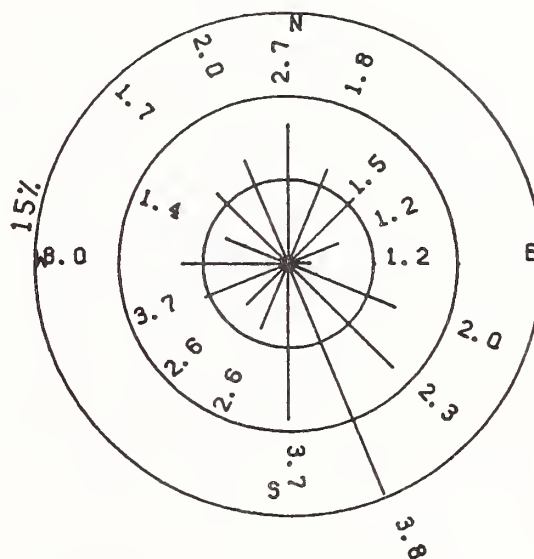
SITE: 820012 RONAN-NINEPIPES MONTHLY

RONAN

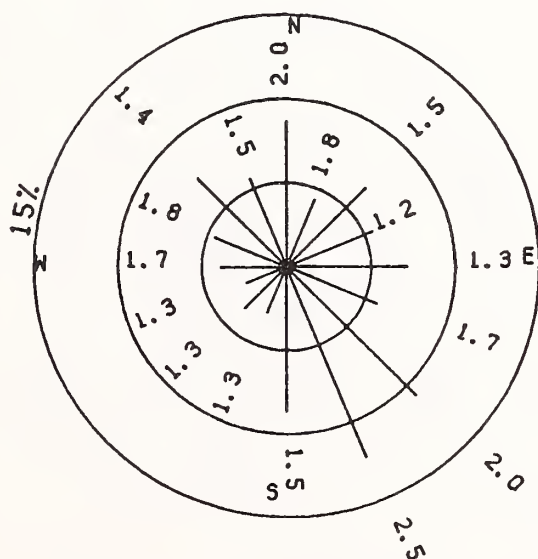
MONTANA



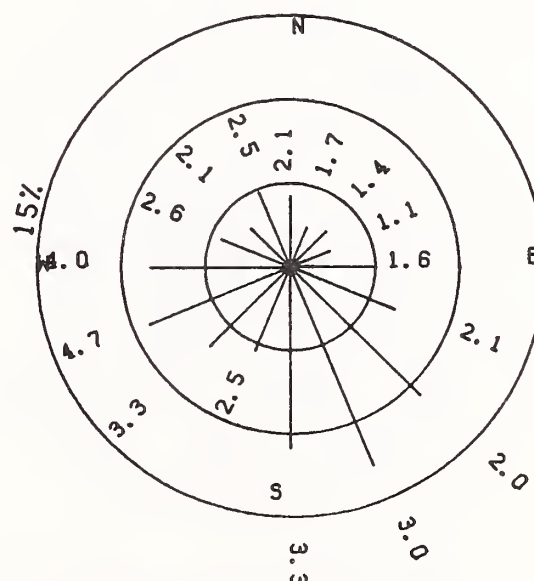
JANUARY 1981
HOURS 0 TO 23
CALM 0.6%
(TOTAL HOURS 645)



FEBRUARY 1981
HOURS 0 TO 23
CALM 0.8%
(TOTAL HOURS 526)



MARCH 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 744)



APRIL 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 704)

FIGURE 7-B

MONTANA

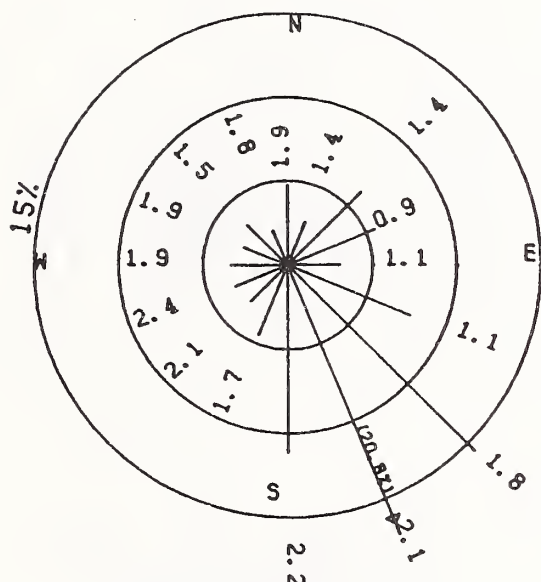
SURFACE WIND ROSES

SITE: 820012 RONAN-NINEPIPES

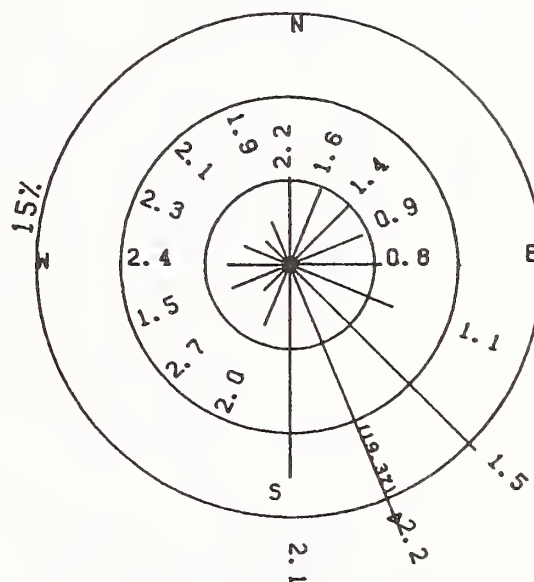
MONTHLY

RONAN

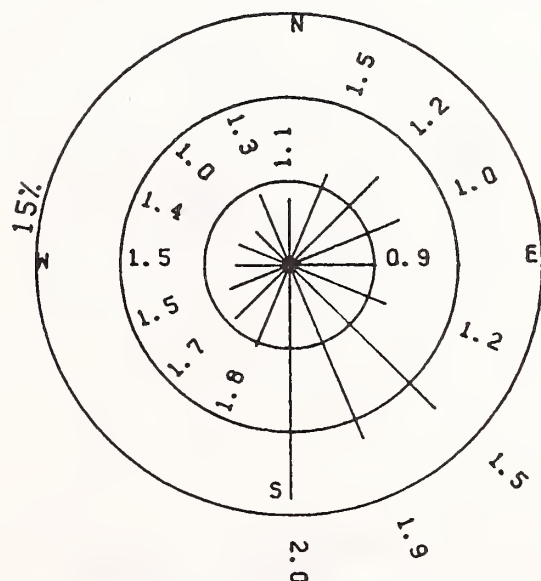
MONTANA



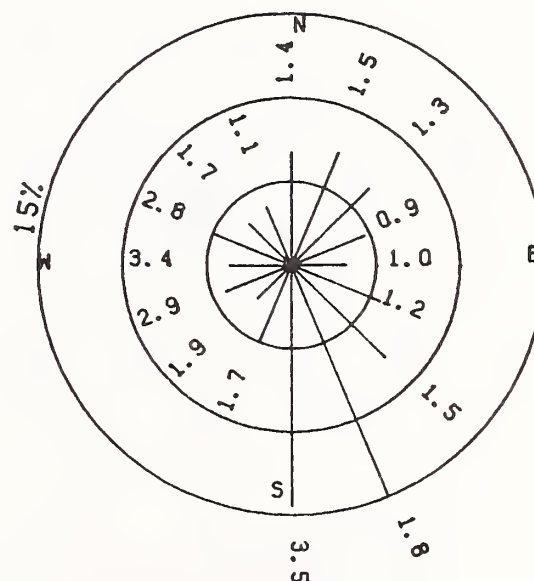
SEPTEMBER 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 360)



OCTOBER 1981
HOURS 0 TO 23
CALM 0.4%
(TOTAL HOURS 516)



NOVEMBER 1981
HOURS 0 TO 23
CALM 0.6%
(TOTAL HOURS 685)



DECEMBER 1981
HOURS 0 TO 23
CALM 1.3%
(TOTAL HOURS 734)

FIGURE 7-D

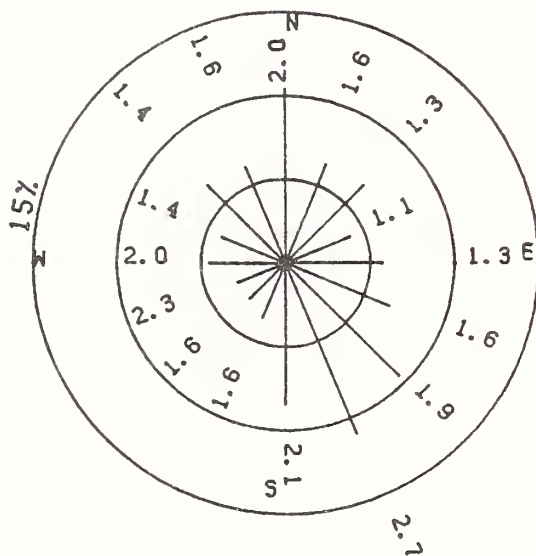
SURFACE WIND ROSES

SITE: 820012 RONAN-NINEPIPES

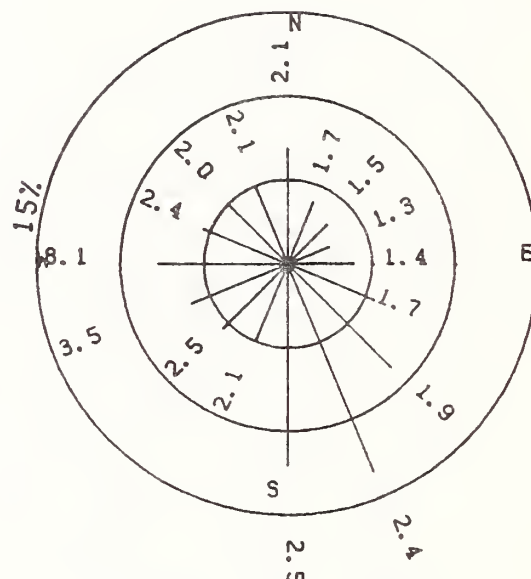
QUARTERLY

RONAN

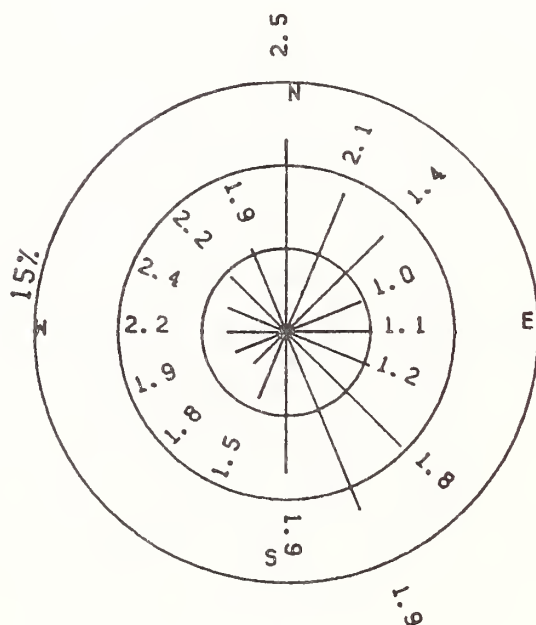
MONTANA



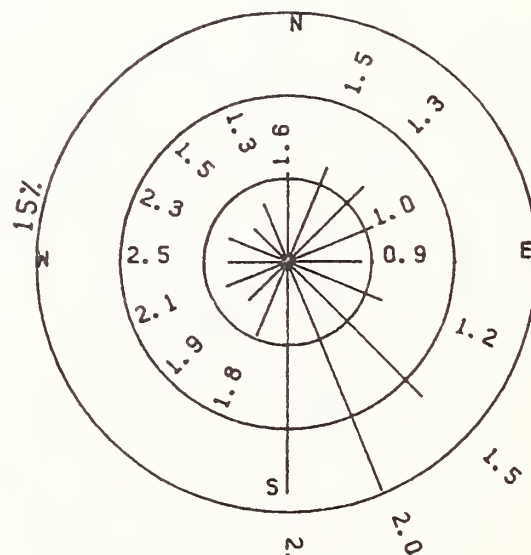
JANUARY - Mar 1981
HOURS 0 TO 23
CALM 0.4%
(TOTAL HOURS 1915)



APRIL - June 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 2120)



JULY - Sept 1981
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 1737)



OCTOBER - Dec 1981
HOURS 0 TO 23
CALM 0.8%
(TOTAL HOURS 1935)

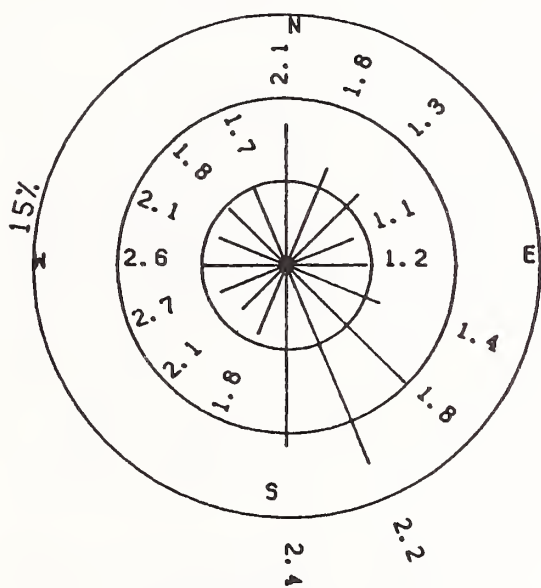
FIGURE 7-E

SURFACE WIND ROSES

SITE: 820012 RONAN-NINEPIPES ANNUAL

RONAN

MONTANA



JANUARY - Dec 1981
HOURS 0 TO 23
CALM 0.3%
(TOTAL HOURS 7707)

FIGURE 7-F

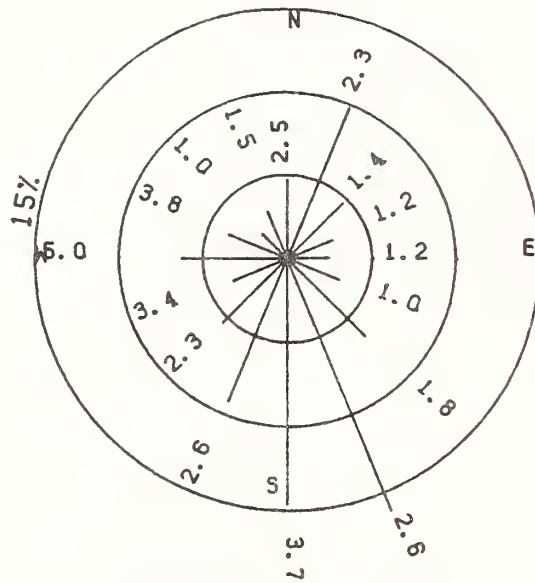
SURFACE WIND ROSES

SITE: 820012 RONAN-NINEPIPES

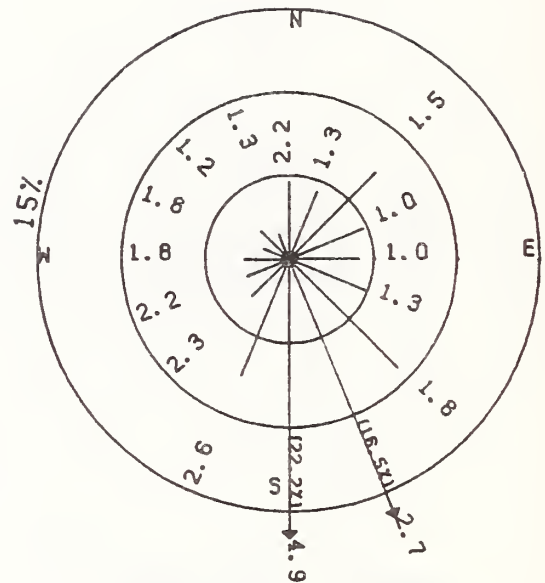
MONTHLY

RONAN

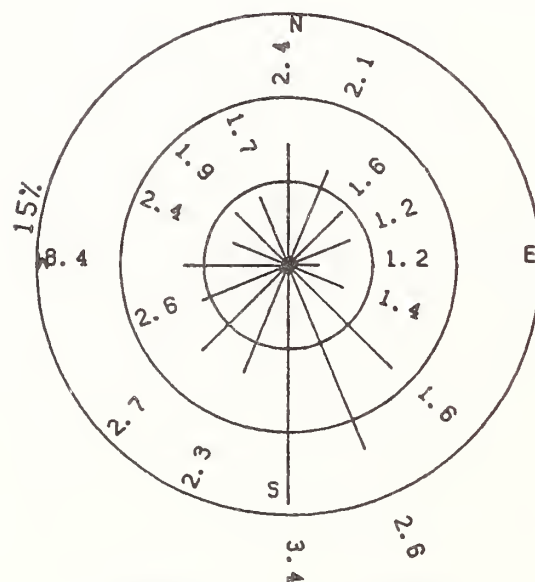
MONTANA



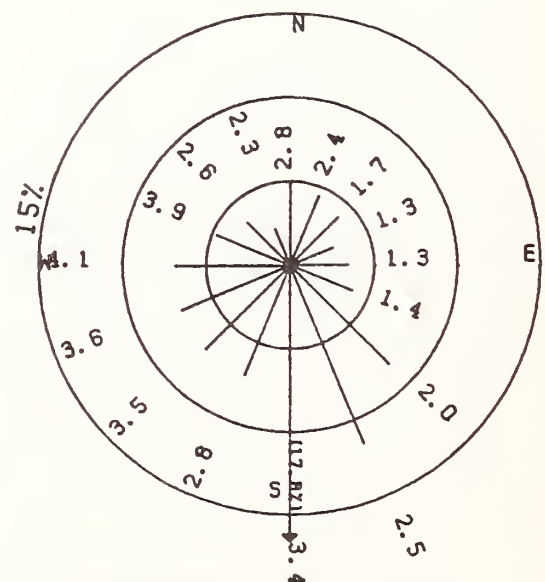
JANUARY 1982
HOURS 0 TO 23
CALM 2.1%
(TOTAL HOURS 708)



FEBRUARY 1982
HOURS 0 TO 23
CALM 0.6%
(TOTAL HOURS 668)



MARCH 1982
HOURS 0 TO 23
CALM 0.1%
(TOTAL HOURS 708)



APRIL 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 720)

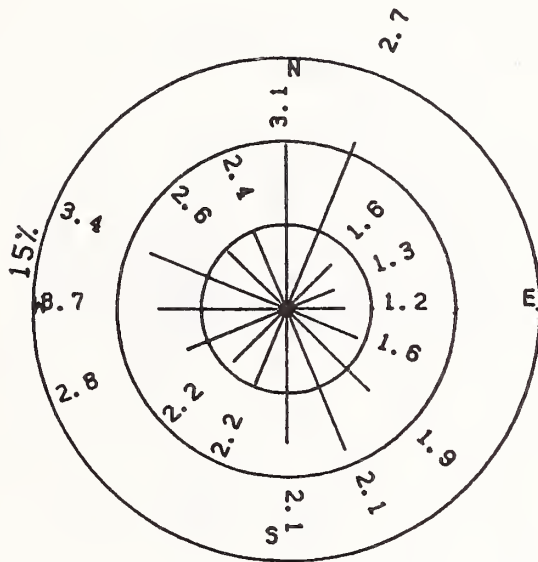
FIGURE 7-G

SURFACE WIND ROSES

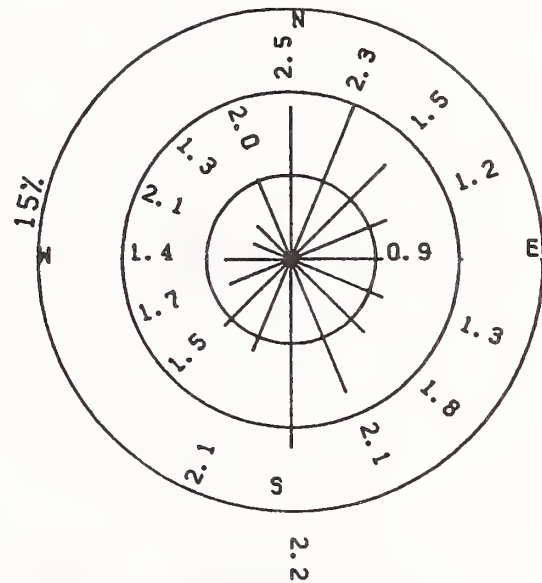
SITE: 820012 RONAN-NINEPIPES MONTHLY

RONAN

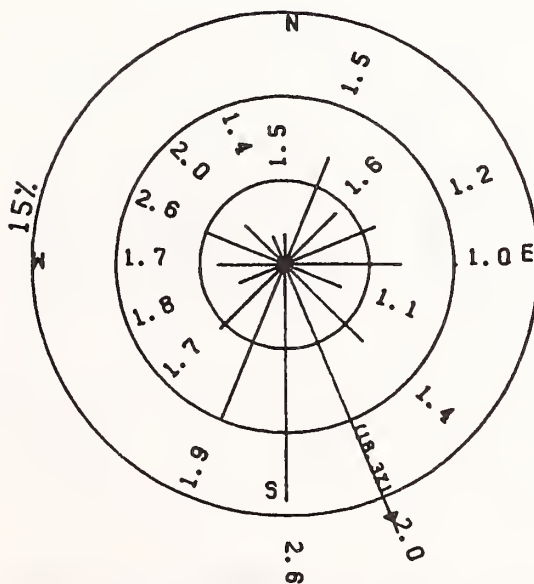
MONTANA



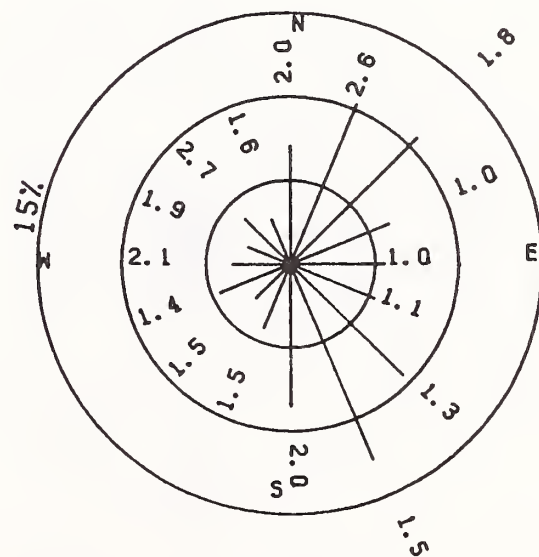
MAY 1982
HOURS 0 TO 23
CALM 0.1%
(TOTAL HOURS 732)



JUNE 1982
HOURS 0 TO 23
CALM 0.7%
(TOTAL HOURS 714)



JULY 1982
HOURS 0 TO 23
CALM 0.0%
(TOTAL HOURS 278)



AUGUST 1982
HOURS 0 TO 23
CALM 0.2%
(TOTAL HOURS 555)

FIGURE 7-H

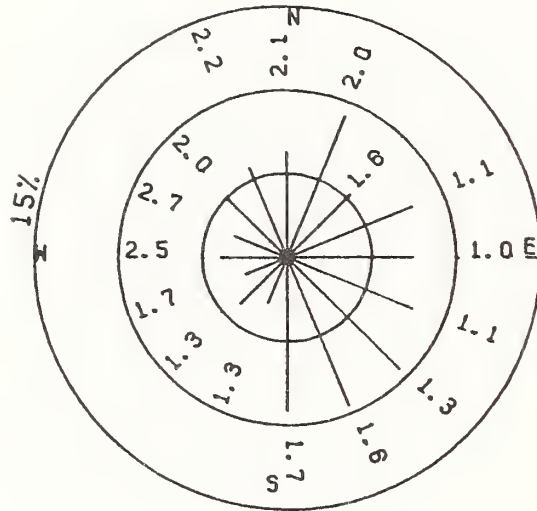
SURFACE WIND ROSES

SITE: 820012 RONAN-NINEPIPES

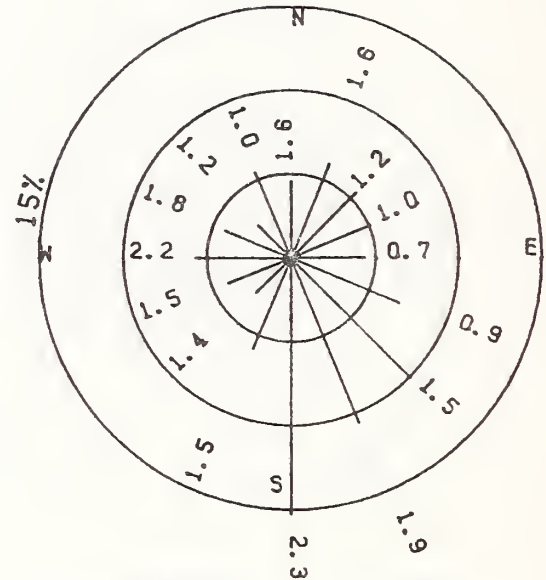
MONTHLY

RONAN

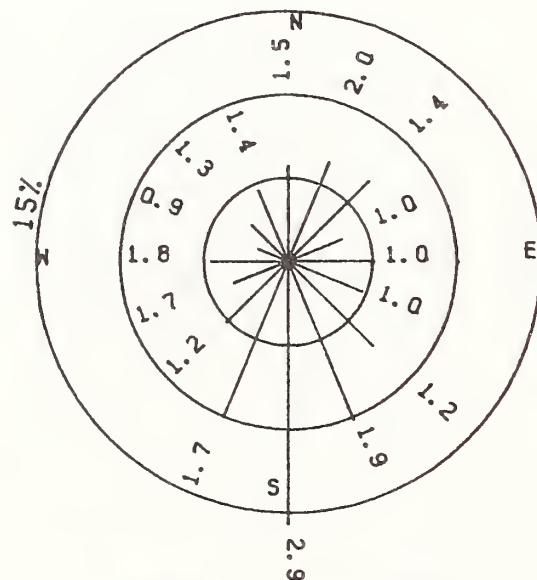
MONTANA



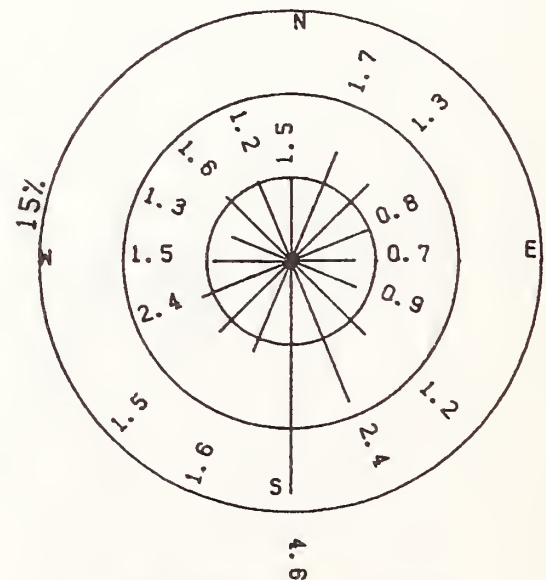
SEPTEMBER 1982
HOURS 0 TO 23
CALM 0.6%
(TOTAL HOURS 712)



OCTOBER 1982
HOURS 0 TO 23
CALM 0.7%
(TOTAL HOURS 543)



NOVEMBER 1982
HOURS 0 TO 23
CALM 2.4%
(TOTAL HOURS 703)

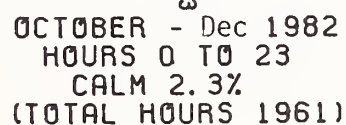
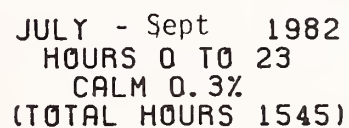
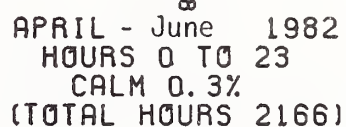
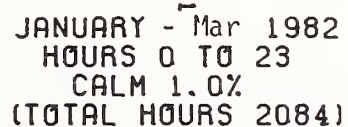


DECEMBER 1982
HOURS 0 TO 23
CALM 3.5%
(TOTAL HOURS 715)

FIGURE 7-I

SITE: 820012 RONAN-NINEPIPES QUARTERLY

RONAN MONTANA



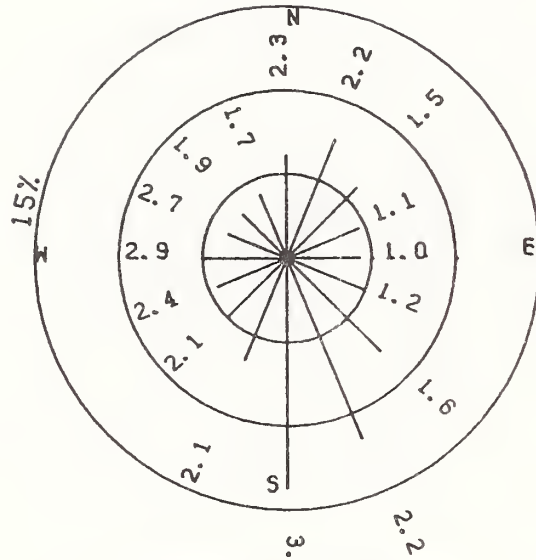
109

SURFACE WIND ROSES

SITE: 820012 RONAN-NINEPIPES ANNUAL

RONAN

MONTANA



JANUARY - Dec 1982
HOURS 0 TO 23
CALM 1.0%
(TOTAL HOURS 7756)

FIGURE 7-K

EMISSION INVENTORY

A. General Methodology

The second goal of the air quality portion of the Flathead River Basin Environmental Impact Study was to identify and quantify emissions of air pollutants. This goal was achieved through two different processes, depending on whether the emissions originated from a major point source or from a group of nonpoint sources. Point sources generally include large industrial plants like the ARCO aluminum plant or the Plum Creek particleboard plant. Nonpoint sources generally include such emission sources as vehicle exhaust, residential fuel combustion, and open burning. Nonpoint source emissions are generally totaled and reported by geographical area and source category.

1. Point Sources

The point source emission inventory was conducted by the Air Quality Bureau as part of the agency's regular duties. The Bureau routinely performs inspections of the major point sources throughout the state. As part of the subsequent inspection report the Bureau updates the agency's computerized emission inventory. The point source emission inventory system includes detailed information on the stack parameters, process throughputs, emissions and control equipment. Figure 8-A is an example of an emission inventory report for a sawmill tepee burner. As can be seen from Figure 8-A, the Air Quality Bureau includes information for many different air contaminants on the point source emission inventory.

Table 5-A summarizes the emissions data for the point sources located in the Flathead River Basin.

2. Nonpoint Sources

The nonpoint source emission inventory was performed on contract to the Air Quality Bureau during 1978 and 1979 (Stewart, 1980). The nonpoint source inventory was completed for sulfur dioxide and particulates and utilized 1978 as a base year.

For the purpose of the nonpoint source emission inventory, the Flathead Basin was divided into square grids varying in size from 20 kilometers down to one kilometer on a side. Remote areas of the basin, which are characterized by few emission sources, were overlayed with a 20 kilometer grid. The grid size generally decreased as the number of emission sources and total emissions increased. Therefore the Flathead Valley itself was overlayed with 5 kilometer grids while the city of Kalispell was broken down even further into a one kilometer grid system. Figure 9-A shows the arrangement of grids throughout the Basin.

Nonpoint source emissions were totaled by ten source categories in each grid. The source categories included: traffic dust off dirt and gravel roads; slash burning; traffic dust off of paved roads; wildfires; vehicle emissions; agricultural activities; residential-commercial-institutional fuel combustion; aggregate storage; railroads; and aircraft emissions. Table 6-A summarizes the nonpoint source emissions for the entire Flathead Basin.

B. Results of the Emission Inventory

1. Particulate

Dirt and gravel roads contribute about three fourths of the total particulate load carried by the Flathead Basin airshed (Table 5-A and 6-A). Almost 90,000 tons of road dust enter the atmosphere annually, the result of an aggregate 45 million miles driven on unpaved roads in the basin each year. Residential areas on the outskirts of the larger cities produce the

greatest amount of road dust because of their combination of heavy traffic volume and many gravel roads. Most road dust particles are larger than 15 microns in diameter and not considered respirable; however, the fine glacial materials which make up many of the valley road beds can be ground into the respirable size range in areas of heavy traffic use.

The intentional burning of logging residue, or "slash" is the second most important source of particulate pollution in the basin. Slash burning adds over 23,000 tons of smoke to the airshed annually, which equals about one fifth of the regional particulate load. Much of the smoke produced by slash burning is respirable particulate. The plume of smoke from intensely hot slash fires characteristically rises to great heights and disperses relatively low concentrations of pollutants over wide areas. Smoldering slash fires, on the other hand, yield up to 10 times (Pierovich, 1979) more particulate per weight of fuel burned and the smoke plume is concentrated in a relatively small area.

Soil tilling for agriculture exposes soil to wind erosion, but most wind-blown soil particles are too large to remain suspended in the air. As a result, the contribution of agricultural activities to the airborne particulate load is relatively minor.

Motor vehicle exhaust, wood smoke from domestic heating, and combustion products from the residential and commercial use of fossil fuels are major nonpoint particulate sources in urban areas. Although these emissions total less than two percent of basin-wide particulate, they contribute significant amounts of fine particulate to the airshed. A 1981 survey of residential wood burning (Erickson, 1981) indicated 30 percent of the homes in Kalispell burn wood as either a primary or auxilliary heat source, producing an estimated 600 tons of primarily fine particulate each year. It is interesting

to note that this figure is significantly higher than the estimate developed as part of the Flathead Emission Inventory and based on the year 1978 (see Table 6-A). In general, ambient levels of fine particulate relate directly to population density, reflecting the urban concentrations of cars, homes, and small businesses which produce much of the fine particulate load.

Most industrial point sources of particulate matter are located near urban centers and thus constitute important local sources of particulate (Table 5-A). A particle board plant, two plywood plants, and six sawmills are located in the vicinity of Kalispell, Columbia Falls, and Whitefish in the upper Flathead River Valley; together, these sources emit almost 1,000 tons of particulate annually. The Anaconda Aluminum Company plant north of Columbia Falls releases an estimated 268 tons per year. Other point sources of particulate pollution include lumber mills at Pablo, Polson and Olney, along with minor particulate contributions from four asphalt plants near Kalispell. Most industrial particulate is in the respirable size category.

2. Sulfur Dioxide

Emissions of sulfur dioxide gas are derived primarily from point sources, in sharp contrast to the non-point origin of most airborne particulate. The Anaconda aluminum smelter is the chief source, annually releasing 2,646 tons, or about 75 percent of total sulfur dioxide emissions in the Flathead Basin. Compared to other metal smelters in Montana, sulfur dioxide emissions from the Anaconda facility are relatively low (less than 10 percent of the annual emissions from the ASARCO lead smelter in East Helena and only about 2 percent of the sulfur dioxide released by the Anaconda copper smelter when it was in operation prior to 1982). Small industrial sources of sulfur dioxide in the Flathead Basin include plywood and particle board manufacturing and dimension lumber processing.

The major nonpoint source of sulfur dioxide is the combustion of fuel oil by residential, commercial, and small industrial users. About one ton of sulfur dioxide is released for each 25,000 gallons of fuel oil burned. Overall, 532 tons, or 15 percent of the total sulfur dioxide load, are produced from nonpoint fuel oil sources. Annual sulfur dioxide emissions from motor vehicles total over 160 tons and depend on both fuel type and engine efficiency. Gasoline powered automobiles have the lowest sulfur dioxide emissions; large diesel trucks release 22 times as much sulfur dioxide per mile as passenger cars. Railroad engines, which also burn diesel fuel, contribute over 100 tons of sulfur dioxide to the airshed each year.

3. Other pollutant sources.

The only source of airborne fluorides in the Flathead Basin is the Anaconda Aluminum Company, which annually emits about 130 tons of gaseous and particulate fluoride. Carbon monoxide and hydrocarbons, both symptomatic of incomplete fuel combustion, enter the basin airshed primarily from motor vehicles exhaust, slash burning, residential wood smoke, and wood processing operations. Nitrogen oxide emissions derive from automobiles and most wood products facilities.

Sample Point Source Emission Inventory Printout

116

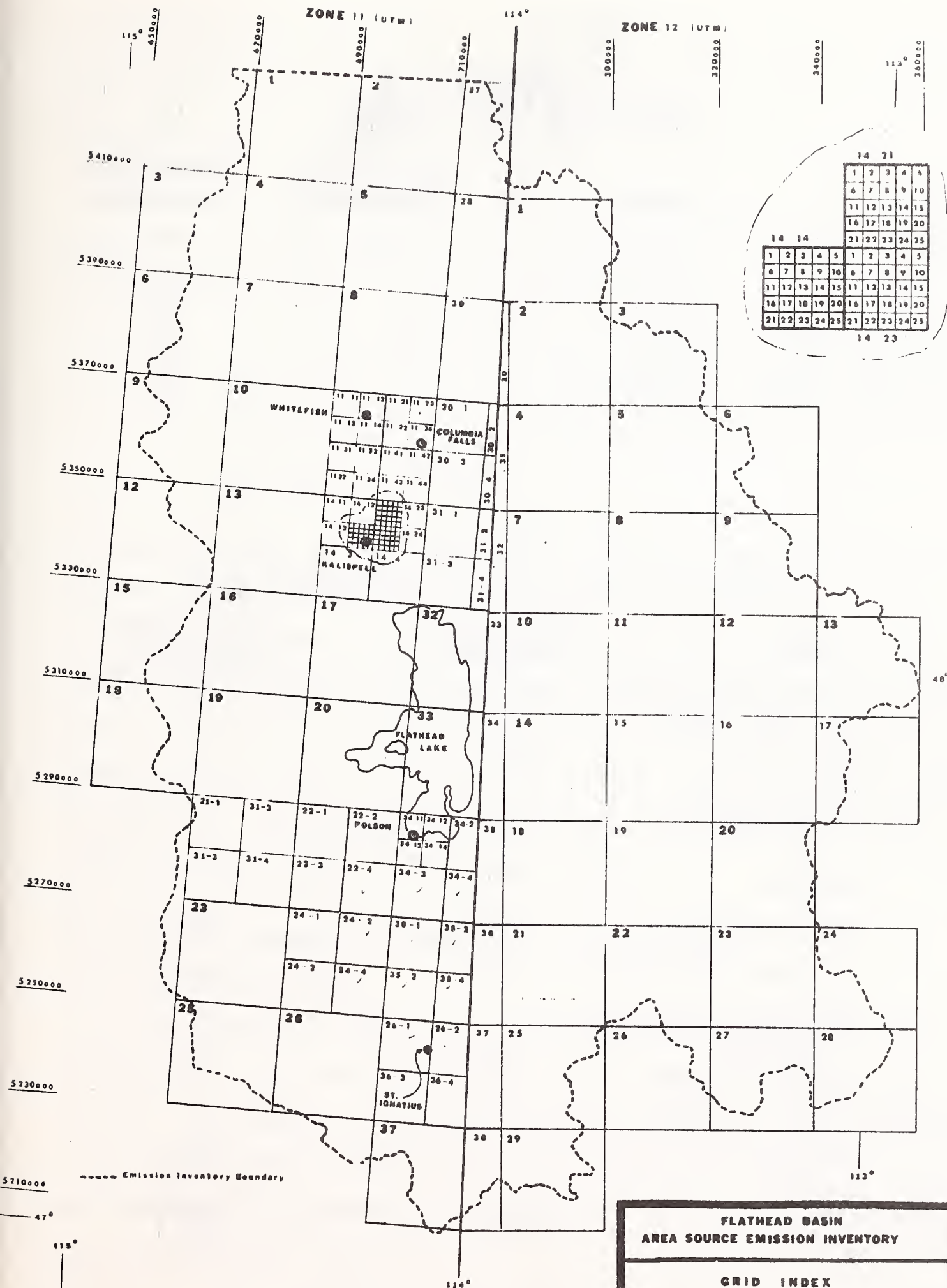


Figure 9 - A
117

TABLE 5-A

Point Source Emission Estimates

<u>Source</u>	<u>Location</u>	<u>Sulfur dioxide (tons/year)</u>	<u>Particulates (tons/year)</u>
ARCO Aluminum	Columbia Falls	2646	268
Stoltze Land and Lumber	Columbia Falls		620
Plum Creek Lumber	Pablo		175
Flathead Lumber	Polson		371
American Timber	Olney		113
Plum Creek Lumber	Columbia Falls		335
Plum Creek Lumber	Kalispell		316

TABLE 6-A

Flathead Basin Area Source Emission Inventory Summary

<u>Source</u>	<u>Particulates (tons/year)</u>	<u>Sulfur Dioxide (tons/year)</u>
Traffic dust on dirt and gravel roads	88,539	
Slash burning	23,704	
Traffic dust on paved roads	853	
Wildfires	356	
Vehicle Emissions	353	161
Agriculture Activities	290	32
Residential, commercial, Institutional fuel Combustion	245	532
Aggregate storage	75	
Railroads	44	101
Aircraft	1	2
	<u>114,460</u>	<u>828</u>

ATMOSPHERIC DIFFUSION MODELING

A. Background

The introduction to this report identified the five goals of the air quality portion of the Flathead River Basin Environmental Impact Study. Goals 4 and 5 are the primary reason for the modeling section of this report.

Goal 4. Develop the capability to assess the effects of man's activities upon the air quality of the Basin.

Goal 5. Develop guidelines to protect and to enhance the air quality of the Basin.

Earlier sections of this report describe the air quality, meteorological, and emissions data gathered over the study period. This information provided the input data to the diffusion models used in the Flathead Study. A preliminary assessment of modeling techniques which would be applicable to the Flathead Basin was performed by a private contractor (Mason, 1983). The actual diffusion modeling was conducted by a second private contractor and is discussed in detail in their final report entitled the "Flathead River Basin Environmental Impact Study Air Quality Modeling Analysis" (Gelhaus, 1983).

B. Preliminary Assessment to Develop a Modeling Study Plan

1. General Procedures

The Department hired an engineering contractor to perform the preliminary assessment and develop a study plan for the Flathead diffusion modeling analysis. The contractor reviewed the topography of the basin, the availability of air quality and meteorological data, and the capabilities of the state's computer system prior to developing a list of modeling options and the associated costs and benefits.

Since the primary objective was to develop a diffusion modeling plan which would characterize the air quality of the Basin or a portion of it, a considerable amount of effort was spent analyzing the physical features of the Basin.

The contractor pointed out that the most overlooked feature in the application of an air quality model is the physical nature of the terrain in which the model is to be applied. In many instances, terrain is not considered simply because the model of choice has no provision to take it into account. Yet the terrain certainly influences the flow of air by channeling it and providing opportunities for upslope or downslope and drainage winds. In addition, the dispersive capability of the atmosphere can be reduced or enhanced due to the increased turbulence generated by terrain features as they obstruct the free flow of air.

Unfortunately, the generally accepted air quality models that do incorporate provisions for terrain features, do so in a very approximate manner and considerable care must be exercised in the interpretation of the outputs from these models. This fact is important during both normal use and during model calibration and verification, especially in the vicinity of terrain features. Still, these models often provide quite usable results at locations remote from prominent terrain features.

The scale of representativeness of each air quality and meteorological monitor was also reviewed. If a model is to perform well, the meteorological input data must be representative of the area to be modeled and the area must contain sufficient air quality data to allow for model verification.

The quality and quantity of all air quality, meteorological and emissions data was thoroughly reviewed to determine its compatibility with diffusion models and to what extent it would limit modeling efforts. It is impor-

tant to consider that any predictive model will only perform as well as the input data supplied to it.

Generally, the more complex and sophisticated a model is, the greater the need for more input data to run it successfully. In this case, more data means not only a greater amount but also greater detail. Certainly, the quantity and detail of the Bureau's meteorological and source emissions data bases set an upper bound to the complexity of the Flathead Basin models.

The contractor also evaluated the state's computer system in regard to modeling capabilities. Both hardware and software features were reviewed. This review was important since computer system limitations could definitely have an impact on the study design. For example, the selection of the most sophisticated and complex model available which utilizes the level of detail associated with the emissions and the meteorological data gathered in the Flathead Study may not be a viable alternative. Because hand in hand with increased model complexity goes an increase in the computer time to run the model and concomitant increased running costs. At some point a balance must be struck between sophistication and practical applicability.

2. Option Development

Upon completion of the review, the contractor developed a list of modeling options varying from "do nothing" (no cost) to developing a comprehensive air model for the entire Flathead Basin (\$6,000,000+). Table 7-A lists the various options with their associated costs and advantages and disadvantages.

3. Analyses of Options and Selection of the Optimum Alternative

The options listed in Table 7-A should be considered a series of stepping stones, each leading to a progressively more complex and, hence, more difficult to attain air quality model. To achieve a successful modeling result

at any given step usually requires that all the preceding steps have been negotiated successfully. Hand in hand with the increase in model complexity goes an increase in the financial resources needed to carry out the model development and verification. Therefore it became obvious that options 7 through 12 were beyond the resources of the Flathead Project.

The contractor also pointed out another limiting factor in model development, namely the amount of air quality data available. For studies in complex terrain, a relatively dense array of sampling sites must be established in order to clearly trace out the areas of plume impaction, as well as to measure the surface concentration patterns for a given source geometry. The scale of representativeness for each Flathead air monitoring site was identified. In no instances did these ranges overlap: one station's effective sampling range did not include any portion of the sampling range of an adjacent station. Consequently, air quality model development and verification could be achieved only on a one station basis and only for that station effective sampling range. The distribution of sampling sites in the Flathead Basin is sparse and therefore would not define the concentration field on a sufficiently fine scale to serve as a basis for the development of a model encompassing a larger region. Only by adding more sampling stations (which was not considered as a viable course of action in the development of the study plan owing to time constraints) could a more complex model be developed and verified. This factor severely limited the options available to the Air Quality Bureau. In fact, only Options 2 through 5 were considered to have any chance of being successfully undertaken given the present data base, and even then it would be necessary to stretch the definition of effective sampling range to achieve that end.

Even with a dense sampling array, however, most of the other options still remained unattainable for reasons beyond the control of the Bureau. To

show this, the contractor considered each of the listed options to assess its feasibility completely independently of any constraints that might have been imposed by any circumstance of the present on-going study.

The first option was simply to do nothing. This was certainly not considered a viable option in terms of the study's goals. These goals obviously would not be attained if this option was exercised, and, at the same time, the wealth of air quality data and meteorological data already acquired would be squandered.

At the other extreme was option 12: the development of an air quality model for the entire Flathead River Basin. This option was also considered not viable at this time. The state of the art of dispersion modeling simply does not permit such a model to be developed now or in the foreseeable future.

One step back from this end of the spectrum were options 10 and 11, both of which were concerned with the development of an air quality model for a limited portion of the Basin which encompasses the complex terrain elements of hills, valleys, and mountains. The same limitation applied here as to option 12, discussed immediately above.

Options 8 and 9 involved the development of an air quality model on a regional scale in terrain of a given type. Again, the state of the art of dispersion modeling has not advanced to the point where even these types of models will be possible in the immediate future.

The next option (number 7) entailed the development of an air quality model for a strictly limited area of the Basin which contained only a single significant terrain feature such as a hill. For the first time in the consideration of the available options, Option 7 could conceivably be done, given sufficient funding.

Some idea of the costs associated with model development and verification in this instance was obtained from estimates prepared by a panel of experts

during a recent EPA-sponsored workshop on atmospheric dispersion models in complex terrain (Hovind, et al., 1979). The panel in fact proposed a complete study involving a single isolated hill with an elevation of from 400 meters to 600 meters.

Altogether the estimated costs for the field work came to \$2,860,000. Additional costs of about \$635,000 for data processing, quality assurance, and data acquisition were added to the above figures for a total of \$3,500,000.

The results of this modeling exercise would still have to be applied to real world topography and verified in that instance (as per options 8 or 9, for example). However, additional funding would have to be made available for this purpose. The contractor estimated the amount of money required to accomplish this to be in excess of \$6,000,000.

The contractor also pointed out that given the Bureau's present fiscal constraints, the development and verification of the option 7 model was not possible. What was possible, however, was the successful completion of any of the models described in options 2 to 5 inclusive. Option 6 requires a denser sampling network than presently exists over the region of possible interest and so was eliminated from consideration. However, given additional funding to permit a better measure of the wind field in the vicinity of the shoreline under a variety of meteorological conditions (including the formation of a land/lake breeze), this option would become viable.

The contractor emphasized that although options 2 through 5 appear simple, the magnitude of the effort necessary to bring each to a successful conclusion should not be underestimated. However, concentrating the AQB's efforts on just these few options would allow attainment of the major air quality goals of the Flathead Basin project. The models developed would serve

those parts of the Basin in which most of the population is located. The models would also be useful in predicting the effects of continued growth and development in precisely those areas in which such future growth is likely to occur. And, finally, the models could be used to assess the impact of new sources on the Class I regions adjacent to and proposed for the Basin. Therefore, the models would serve a very useful and real purpose, although they would apply to only a very limited portion of the entire Basin.

The ability to develop these models successfully lies in the completeness of the Bureau's source emission and meteorological data bases. The source emission inventory, adequately defines the source strengths and source geometry for the purpose of constructing the required models. A sufficient number of meteorological stations have been situated in the regions of interest to adequately define (for modeling purposes) the meteorological parameters necessary as input to these models. A significant enhancement of the meteorological data results from the use of acoustic sounders at the primary meteorological facilities. The acoustic sounder data provides information on the mixing height or the height of the base of an inversion and also allows atmospheric stability to be determined. Even in the event that sounder data is missing, stability can be obtained indirectly from the wind speed and insolation recorded at the primary sites. Consequently, the Bureau's data base for the Basin contains all the required input parameters that most dispersion models require.

The contractor suggested that the particular models to be developed and verified should probably come from the standard repertoire of already developed EPA approved models. There is no special benefit in attempting the development of a different type of model for the options under consideration. Since the AQB would be limiting itself to relatively simple terrain types, the standard EPA approved models should be expected to work as well as they normally do. A model

should be selected which requires input on an hour by hour basis and that utilizes dispersion coefficients appropriate to the terrain and land use being modeled. The rural and urban versions of the RAM model might prove to be most useful here. However, for the modeling of TSP, the Industrial Source Complex (ISC) model might prove even more useful because of its provision for using effluent settling velocities when these are known.

Although there is only one sampling station to compare model predictions to in any given region covered by the model, a change in wind speed or wind direction or stability effectively changes the position of the sampler with respect to the sources contributing to it. In that sense, if the model is run on an hour to hour basis, and a high correlation is obtained between predictions (for any sampling interval) and the measured concentrations (for the same sampling interval) for a large number of cases under different prevailing weather conditions, then the model can indeed be considered as having been verified.

Upon completion of the preliminary assessment, the Air Quality Bureau selected option number 5 as the best alternative. Option 5 allows for the delineation of individual airsheds and the application of standard EPA approved diffusion models to each airshed. The areas to be modeled lie on the valley floor and generally encompass the area of higher population and highest potential for economic growth. As can be seen in the following discussions, this general study plan was utilized during the actual modeling project.

C. Diffusion Modeling Analysis

The Air Quality Bureau hired a local contractor to perform the actual modeling study. They generally followed the study plan developed during the preliminary assessment. However, prior to executing any models, they prepared the meteorological and emission inventory data into a form suitable for modeling analysis. In addition airshed boundaries were determined and the diffusion models best suited for the various airsheds were selected.

1. Preparation of Meteorological Data

a. Data Assessment

As a method of assessing the meteorological data prior to selecting representative periods for use in the diffusion models, an audit of meteorological data was performed. A preliminary screening of the entire data base was conducted to narrow the data to a 15 month period representing the most complete data. The data from this 15 month period was checked further for completeness and reasonableness while spot checks were made to assure that the computerized data agreed with the raw data recorded on strip charts.

Based on the audits and the data completeness, the preliminary data periods were narrowed to the best one year periods for the six sites where wind data was measured. Because of missing data, variations in these one

year periods were made to allow the compilation of the most complete data sets. Table 8-A lists the general data periods selected for each site.

b. Methods to Handle Missing Data

The meteorological data sets from each of the monitoring sites were reviewed on a day by day basis and missing or bad data was identified. The contractor used several methods to fill the gaps or replace poor data. These methods were:

1. Month replacement
2. Interpolation
3. Calm wind adjustment
4. Use of another monitoring site

Months that had extensive missing data (greater than 50 percent) were marked for replacement. Previous years were reviewed to determine if better data completeness was recorded during the same month in a different year. If this was the case, all parameters involved were replaced by the new month (wind speed, wind direction, temperature, stability, and mixing height). The second data gap filling method used was interpolation. If a day had two or less hours missing in a row, these values were replaced using an interpolation of the previous and following hourly values. The third method of data gap filling involved the calm winds. The standard Gaussian dispersion equation will not accept calm winds. Therefore, any wind speed less than 1.0 meters per second but greater than 0.0 meters per second was increased to 1.0. Wind speeds of 0.0 meters per second were assigned the previous hour's wind speed and wind direction unless more than two hours were calm. The fourth data gap filling method was to utilize data from another monitoring site deemed representative of the site of concern. This frequently occurred in regard to temperature, stability and mixing height data.

c. Data Completeness

Following the data gap review, the contractor prepared tables of final data recoveries (Tables 9A through 9F). The tables show the various months that were substituted and the source of the data used. Data from alternate monitoring sites was frequently used for mixing height data which was available from only two sites.

d. Stability Frequency Decks

The final data sets were then input to a computer program that tallied the stability, wind speed and wind direction data into stability frequency decks (commonly called STAR decks). The STAR decks list the data in percent frequencies of six wind speed categories versus sixteen wind direction intervals for each of six stability classifications. STAR decks were created for each of the sites.

e. Preprocessed Hourly Data Decks

Similar to the STAR decks, the contractor processed the hourly meteorological data through a computer program to prepare the hourly data for entry into short term diffusion models such as CRSTER and ISC. The preprocessed meteorological decks contain an entire year of representative hourly data and are therefore extremely long. The Air Quality Bureau stores this information on magnetic tape and copies can be obtained.

f. Delineation of Airsheds

Following the meteorological data review, the contractor determined that reliable data was available for six monitoring sites in sufficient quantity to allow for diffusion modeling analysis. The general topography, meteorological data, and available air pollution emission data were reviewed to determine the area (airshed) best described by the data available. The

airshed boundaries and size varied greatly from site to site especially due to terrain. The final airshed designations were determined after consultation between the contractor and the Air Quality Bureau. Figure 10-A shows the entire Basin, the location of the monitoring sites and the airshed boundaries.

The primary reference for the point source data was the AQB emission inventory listing. Modifications were made by the contractor where necessary based on recommendations of the AQB. The emissions were modified to account for seasonal variations in emission rates. The fugitive dust emissions from the point source inventory were given a fixed plume height of 10 meters with no plume rise beyond 10 meters allowed. The fixed plume height was used since the fugitive dust sources generally had undefined exit velocities, stack diameters or stack heights.

The area source emissions were taken directly from the Flathead River Basin Area Source Emission Inventory (Stewart, 1980). The only changes made were to attach seasonal scalars to weight the emissions of such sources as paved and unpaved roads, agricultural tilling, slash burning, and wood fuel usage to match emission rates to the seasons of the year.

g. Model Selection

In order to select appropriate diffusion models, the contractor performed a review of the available model input data, the physical nature of the Basin, and the available diffusion models. Based on the Environmental Protection Agency Guidelines on air quality models and discussions with the AQB, one short term and one long term diffusion model were selected for each airshed. An attempt was made to select only EPA recommended models for "refined" analyses. Only for the North Fork of the Flathead River were screening models selected. The primary variables affecting the selection of the models were:

Pollutant: Particulates

Time Period: Annual, 24-hour

Source Types: Area, Point (Multiple)

Urban, Rural Mode: Urban

Terrain: Small variations except the North Fork Airshed

The EPA Guideline document lists the Industrial Source Complex (ISC) model as the only applicable refined model for the various criteria listed. The ISC model is actually two models: ISCLT (long-term) and ISCST (short-term). For the North Fork of the Flathead River, terrain complexities made the model selection very limited. The EPA recommended "screening" model is the VALLEY model. The VALLEY model was selected for the annual period simulation. For the short term (24-hour) analysis, a multiple box model designed by the contractor was selected. The box model allows up to nine boxes of varying size and orientation to be simulated. Hourly meteorological data are input for up to 120 hours. Concentrations of air pollutants are listed for each hour and box simulated.

The ISCLT model (long term) is a steady state Gaussian plume model which can be used to assess pollutant concentrations from a wide variety of sources associated with an industrial source complex. The model can account for settling and dry deposition of particulates; downwash; area, line and volume sources; plume rise as a function of downwind distance; separation of point sources; and limited terrain adjustment.

The ISCST model (short term) is similar to the ISCLT model but calculates concentrations of pollutants for 1, 2, 3, 4, 6, 8, 12 and/or 24-hour time periods.

The VALLEY model is a steady state Gaussian plume model designed for estimating either 24-hour or annual concentrations resulting from emissions

from up to 50 point and area sources. Calculations of ground level pollutant concentrations are made for each frequency designated in an array of stability and wind occurrences (STAR deck) and 112 receptor sites on 16 radials. Plume height is adjusted according to terrain elevations and stability classes.

2. Modeling Results

a. North Fork

The contractor utilized two models on the North Fork of the Flathead River. The first model was the multiple box model for short term particulate concentrations. The second model used was the EPA VALLEY model. For the box model analysis the upper North Fork area was divided into six boxes, each five kilometers long starting with the first box at the U.S.-Canadian border. The box widths varied with the valley widths. Analyses were performed on the six boxes using three methods. They were: (1) varying each individual box width; (2) varying the natural particulate removal rate; and (3) using different time periods.

The box widths were varied by specifying three height differences between the valley floor and the maximum top of a box wall. The heights used were 1600, 800 and 200 feet. Emission rates for the existing area sources in the valley were input. New sources such as the Cabin Creek Mine were included in later model simulations.

The particulate removal rates varied from 0 percent to 20 percent per hour. The total mass of particulates in each box at the end of the hour was reduced by the rate simulated for that model run.

The time periods simulated were three separate five day (120 hour) periods occurring during 1979 and 1980. The dates selected were the same periods previously used by the Air Quality Bureau in an analysis of the

Cabin Creek Mine. The dates included periods of near stagnation conditions with a northerly wind flow.

The maximum predicted particulate value was 16.4 micrograms per cubic meter. This occurred with a 200 meter box height and with no particulate removal.

For the long term model simulation of the North Fork Airshed, the VALLEY model was run using emissions from the existing area sources in the region. The model simulated concentrations in a 12 kilometer radius centered 12 kilometers south of the U.S.-Canadian border. The model utilized the STAR deck constructed from the Big Prairie wind data and the Glacier International Airport stability data.

The maximum concentration predicted for the annual period in the North Fork airshed was 17.6 micrograms per cubic meter. Concentrations varied from a low of 3.2 micrograms per cubic meter near the west edge of the airshed to 17.6 micrograms per cubic meter at the east edge. The maximum annual value exceeded the maximum 24-hour value predicted by the box model. This difference is mainly due to the location of the concentrations. The box model predicted only for valley locations whereas the VALLEY model maximum occurred in the elevated terrain in Glacier National Park.

The North Fork airshed was also modeled for emissions from the proposed Cabin Creek Coal Mine. The Mine was modeled for both the short and long term periods and for both sulfur dioxide and particulate matter. The short term model used was the multiple box model with seven boxes working south from the mine down the North Fork of the Flathead River. Three five day periods (the same periods as previously discussed) were simulated with the box model with concentrations calculated for each one hour period. The emission rates used are listed in Table 10-A.

The meteorological data used in the box model was obtained from wind data at the Big Prairie monitoring site.

The long term model used was the VALLEY model. The model calculated concentrations at 112 receptor points in 16 radials extending from a center near Polebridge. Radials were extended far enough to include the U.S.-Canadian border and various areas of Glacier National Park. The model used a STAR deck prepared from wind data at Big Prairie and stability data at Glacier International Airport. The emission rates listed in Table 10-A were also used in the VALLEY model.

Table 11-A shows the average increase in concentration for the 15 days simulated and the maximum 24-hour concentration increase. Box 1, the box starting just south of the U.S.-Canadian border was exposed to the highest concentrations as expected. The maximum particulate increase for a 24-hour period varied from 33 to 58 micrograms per cubic meter, depending on the mixing height and removal rate. Since Box 1 contains a portion of Glacier National Park, a Class I area, the maximum 24-hour particulate level is compared against the Class I particulate matter increment of 10 micrograms per cubic meter. The maximum 24-hour increase of sulfur dioxide was 17.5 micrograms per cubic meter which is also above the Class I sulfur dioxide increment of 5 micrograms per cubic meter.

Table 12-A summarizes the VALLEY model annual concentration increases due to the Cabin Creek Coal Mine. Also shown in Table 12-A are the Class I and II increments available. The maximum annual sulfur dioxide level predicted exceeds the Class I increment but is far below the Class II increment. The maximum annual particulate level predicted exceeds both the Class I and II increments. The location of the maximum predicted particulate concentration actually occurred west of the North Fork of the Flathead River in a Class II area.

The North Fork airshed was also modeled using the multiple box model and the VALLEY model for two hypothetical gas flares near Polebridge. The same periods and meteorological data sources used for the coal mine were used in the gas flare models. Table 13-A lists the emission rates used in the analysis for both models.

The maximum 24 hour sulfur dioxide concentration predicted was 30.5 micrograms per cubic meter. This concentration is substantially above the Class I increment of 5 micrograms per cubic meter, but below the Class II increment of 91 micrograms per cubic meter. Only the box containing the gas flares was predicted to receive impact of sulfur dioxide.

Table 14-A summarizes the Box and VALLEY model results for the two flares. The PSD Class I and II annual increments are also shown for comparison. The location of the predicted annual maximum was south of the source and within one kilometer of the source. This location is not in Glacier National Park (Class I area). However, the predicted annual concentration of 19.8 micrograms per cubic meter is very near the Class II increment.

b. Other Airsheds

The contractor modeled the remaining five airsheds using the Industrial Source Complex (ISC) model for both the short term (24 hours) and long term (annual) periods. The models were executed three times in most cases. The preliminary run of the models utilized a two-kilometer receptor grid and the large area sources from the Flathead Basin Area Source Inventory (some sources at least six miles on a side). During this model run all receptors were eliminated by the model as they were located too near or within an area source. The first usable run of the models (Run 1 on the following tables) continued to use a two kilometer receptor grid. However, in Run 1 the area sources were broken into one kilometer squares located inside the two kilometer grid. The emission rates were also scaled upward to account for the reduced area source size.

In Run 2 the locations of the point sources and monitors were plotted on a 7-1/2 minute USGS map as precisely as possible using aerial photographs and available inspection reports. These more accurate locations were then input into the model. In addition, all fugitive dust sources associated with point sources were re-input into the model as area sources with the best available area source descriptions.

Table 15-A compares the predicted annual concentration for run 1 with the actual measured values. The model varied by airshed but generally under predicted the actual results. Table 16-A is an example of the results for Run 1 of the short term model for the Kalispell airshed and the Universal Athletics monitor location. Due to the volume of data available for the short term period, only the data for the Universal Athletic site is displayed. Table 17-A summarizes briefly the short term model results for all airsheds and monitoring sites. Table 17-A shows that the average model prediction was generally below the measured value. Only at the Airport and the Evergreen sites did the model over predict. In addition, the maximum model prediction was generally below the measured value and also occurred on different days.

Table 18-A compares annual concentrations predicted by run 2 of the ISCLT Model with the monitor results. Run 2 was not performed on the Bigfork airshed since the airshed contained no point sources to be redefined. Model results changed significantly from run 1 in the Columbia Falls, Polson, and Kalispell airsheds. As a result of the second run the model now under predicted the concentrations at both Columbia Falls monitor sites. The Anders site prediction dropped from 391 to 38 micrograms per cubic meter. The NAAC site predicted concentration showed little change.

The Polson site revealed an increase from 20 to 67 micrograms per cubic meter compared to the measured of 45 micrograms per cubic meter. The Universal Athletic site revealed little change. However, the predicted concentration at the Evergreen site dropped from 274 to 119 micrograms per cubic meter, whereas the Airport site increased from 16 to 124 micrograms per cubic meter. These values compared to the measured value of 61 micrograms per cubic meter. The sites that had the greatest change generally had fugitive dust sources located nearby.

The Kalispell airshed was also remodeled for the short term period using the refined source data (run 2). At all three sites the models under predicted the actual concentrations. Only the Kalispell airshed was remodeled in Run 2 for the short term period in order to test the new emission source layout. Since the new method did not improve the model results, no additional airsheds were simulated.

3. Model Evaluation

The airshed modeling results for the first and second runs of the models were evaluated using several different methods. Both the long term and short term model results were evaluated. Tables 19-A through 23-A summarize the model evaluations for the various monitor locations. Table 19A displays the model accuracy for the annual particulate concentrations for runs 1 and 2. The residual is defined as the measured concentration minus the predicted. In Table 19-A all but two residuals are positive for Run 1, varying from 12 at NAAC to 45 at the Airport and Universal Athletics monitor locations. At the Anders location the residual was -259 and at Bigfork -100. In the second run at several sites the residuals reversed signs and the overall average residual appeared better.

Table 20-A summarizes the accuracy for the short term model results. Two evaluations are present: (1) the accuracy based on space and time and

(2) the accuracy based on space only. Shown in Table 20-A are the maximum and second highest concentration residuals. The space and time residuals varied greatly from location to location. The worst residuals were at the Anders location (maximum = 293) in the first run and at the Airport in the second run (maximum = 301). The best residuals were at the NAAC (maximum = 45) and Ninepipe (maximum = 43) locations. Using the space only residuals the results do not change appreciably except at the Evergreen site. Only the Evergreen site made a change from a positive to a negative residual for both maximum and second highest concentration. The residuals for Bigfork are misleading as the model never predicted above 0.01 micrograms per cubic meter. Therefore, the residuals are essentially the measured value minus zero.

Table 21-A summarizes the precision or performance measure for gross variability for the short term models. Shown in Table 21-A are both the mean absolute residual and the mean square error. The mean absolute residuals varied from 98 at Universal Athletic to 14 at NAAC. The mean square error analysis resulted in very high values. Results varied from a low of 320 at NAAC to a high of 15,768 at the Airport. No results are shown for Bigfork as the numbers are meaningless based upon the discussion in the previous paragraph.

The evaluation of the short term modeling results also included use of the Student's "t" test. As a test of randomness, the residuals were subjected to a "runs" test. Table 22-A summarizes the results of the Runs test and the Student's "t" test. The data from the Polson site failed the Runs test indicating the variance of the residuals about the mean was not random. The remaining sites passed the runs test. Table 22-A also lists degrees of freedom, the "t" values, and the critical "t" values. In the case of the "t" test, the null hypothesis is that the mean of the

predicted values is equal to the mean of the measured values. If the "t" value calculated is greater than the critical "t" value, the null hypothesis must be rejected. In all cases the null hypothesis is rejected. Only for the Evergreen and Airport sites on the first run were the "t" values even close to not being rejected.

The final evaluation of the short term modeling results consisted of the calculation of a linear regression and correlation coefficient for the measured versus predicted values. Table 23-A summarizes the regression coefficients and the correlation coefficients. The correlations ranged from -0.31 at Evergreen to 0.52 at Polson. The Polson, Ninepipe, and Columbia Falls airshed models appeared to predict the best based on the correlation coefficient. The second run on the Kalispell airshed improved the correlations for the Evergreen and Airport sites.

4. Modeling Summary

The air quality modeling effort proved to be a valuable analysis, despite the poor comparisons between measured and predicted concentrations. The meteorological and air quality data collected over the life of the Flathead River Basin Environmental Impact Study was compiled, audited and the best data periods assembled into diffusion model compatible sets. The emission inventory data was also verified and assembled in diffusion model compatible files. Six distinct airsheds in the basin were designated and the appropriate meteorology and emission data assigned to each airshed.

Various modeling runs were made with varying degrees of success. The models used in the North Fork of the Flathead River (Box model and VALLEY model) agreed fairly well with monitor results. However, the ISC model used in the major portion of the analysis did not perform as well. In the annual mode the ISC models did compare reasonably well with the monitor results. In Run 2 the results of the model generally underpredicted the

actual concentrations. The most likely cause of the under prediction was the area source emission inventory. The area source emissions data did not adequately describe the magnitude of the emissions especially for sources very near the monitor locations. The short term model results varied much more than the long term results. However, again the models generally under predicted the actual concentrations.

The data bases and models prepared under this analysis will be very helpful in assessing the impact of new or modified air pollution sources. However, the models will not replace the need for pre and post construction monitoring.

Other models could have been tested on the emission and meteorological data if additional time and funds had been available. However, because of the complex airflow and the variety of emission sources in the basin, it is doubtful that any EPA or non EPA approved model would have performed better than ISC. The degree of sophistication of the diffusion models available and the limited number of meteorological monitoring sites limit the accuracy of the predictions especially in complex airflow regions such as the Flathead Basin.

**FLATHEAD RIVER BASIN
ENVIRONMENTAL
IMPACT STUDY
STUDY AREA MAP**

Monitoring Sites

- 1) Moose City
- 2) Polebridge
- 3) Col. Falls - NAAC
- 4) Col. Falls - Anders
- 5) Kalispell-Airport
- 6) Kalispell - Strom
- 7) Kalispell-Univ. Ath.
- 8) Kalispell-Evergreen
- 9) Big Fork
- 10) Polson
- 11) Ronan
- 12) Ninepipe
- 13) Whitefish
- 14) Swan Youth Camp
- 15) Ronan (tribal)
- 16) St. Ignatius (tribal)
- 17) Arlee
- 18) Evaro

Airsheds

- A. North Fork
- B. Columbia Falls
- C. Kalispell
- D. Bigfork
- E. Polson
- f. Ninepipe

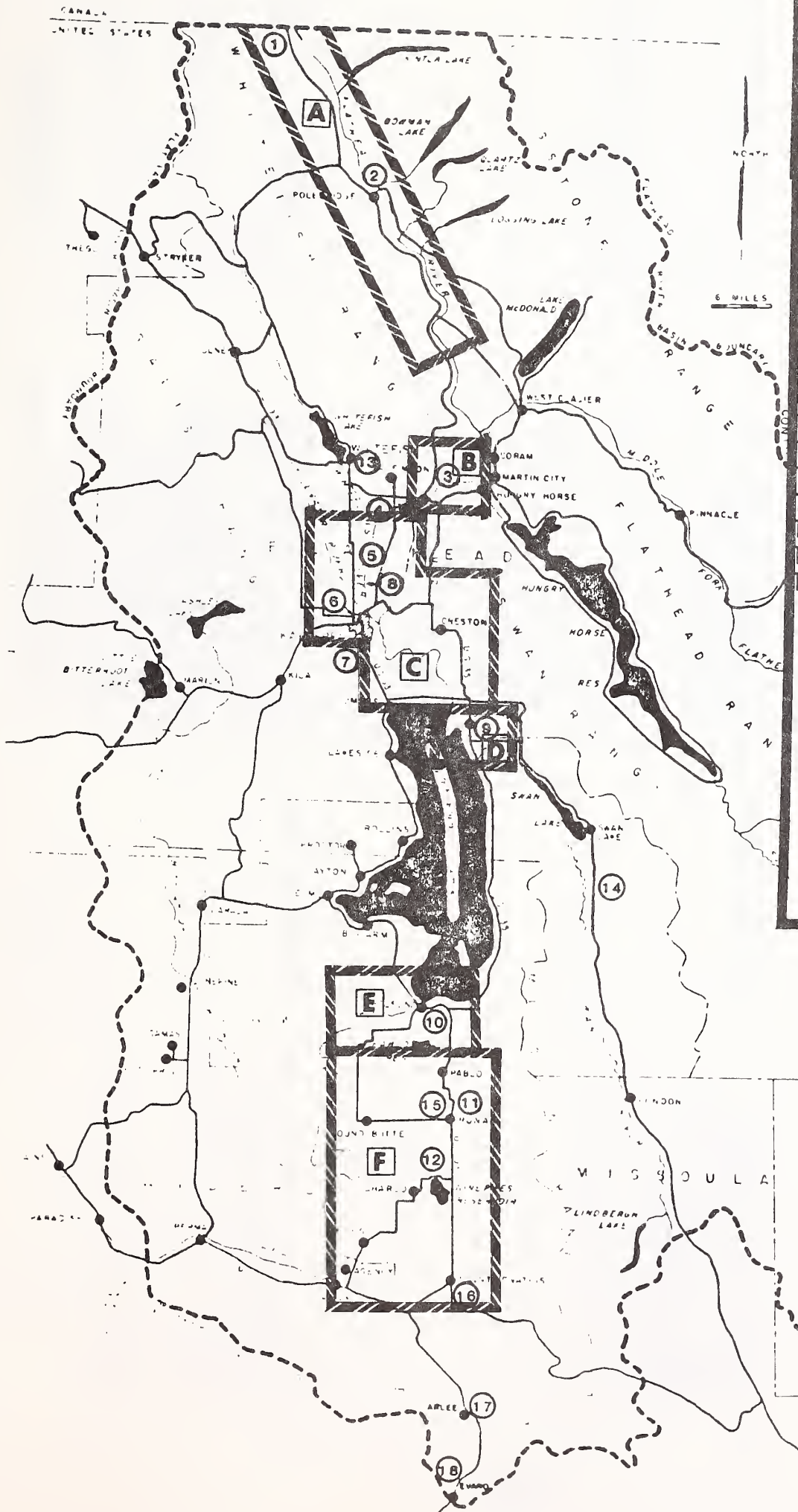


TABLE 7-A

Flathead Study
Diffusion Modeling Options

<u>Option</u>	<u>Cost</u>	<u>Advantages</u>	<u>Disadvantages</u>
1. Do nothing	No cost		1. Fails to accomplish project goals.
2. Develop an air quality model on the neighborhood scale for fairly flat terrain (Whitefish, Ronan, etc.)	\$15,000-\$25,000	1. On a very limited basis, partially fulfills the project goals. 2. Uses all available input data for the applicable 3. Can be used to predict impacts of future growth and development on these specific areas of the Basin. 4. Within the project budget.	1. Does not allow for analysis of complex terrain areas of the Basin. 2. Only provides for analysis of small areas located on the valley floor.
3. Develop an air quality model on the regional scale for fairly flat or uniform terrain (airport, Ninepipe, etc.)	\$15,000-\$25,000	1. On a very limited basis partially fulfills the project goals. 2. Uses all available input data for the applicable areas of the Basin. 3. Can be used to predict impacts of future growth and development on these areas of the Basin. 4. Within the project budget.	1. Does not allow for analysis of complex terrain areas of the Basin. 2. Only provides for analysis of small areas located on the valley floor.

<u>Option</u>	<u>Cost</u>	<u>Advantages</u>	<u>Disadvantages</u>
4. Link models developed in options 2 and 3 above where and if appropriate.	\$30,000-\$50,000	1. Partially fulfills the project goals. 2. Uses all available input data without requiring more. 3. Provides analysis for the most important part of the Basin--most populated areas. 4. Can be used to predict air quality impacts from future growth and development. 5. Can be used to predict air quality impacts from future growth and development on adjacent Class I areas. 6. Within the project budget.	1. Does not allow for analysis of complex terrain areas of the basin
5. Develop an air quality model on the neighborhood scale at a shoreline site flat terrain (Polson). (includes cost of option 4)	\$35,000-\$55,000	1. Partially fulfills the project goals. 2. Uses all available input data without requiring more. 3. Provides analysis for the most important part of the Basin--most populated areas. 4. Can be used to predict air quality impacts from future growth and development. 5. Can be used to predict air quality impacts from future growth and development in Class I areas. 6. Within the project budget.	1. Does not allow for analysis of complex terrain areas of the Basin.

<u>Option</u>	<u>Costs</u>	<u>Advantages</u>	<u>Disadvantages</u>
6. Develop an air quality model on the regional scale at a shoreline site in flat terrain (Polson with additional samplers (includes cost of Option 4).	\$40,000-\$60,000	1. Partially fulfills the project goals.	1. Requires additional meteorological and air quality monitoring. 2. Allows for analysis of valley floor areas only. 3. Substantial additional costs for
7. Develop an air quality model on the neighborhood scale in terrain having one single significant feature such as an isolated hill.	\$3,500,000	1. Partially fulfills the project goals. 2. Very limited analysis of terrain features.	1. Requires research to extend the present state of the art to this specific application (tracer studies, etc.) 2. Extremely limited in regard to terrain features and probably would not extend the analysis area outside of the valley floor. 3. Beyond the project budget. 4. Would require additional computer software.
8. Develop an air quality model on the regional scale in hilly or gently rolling terrain.	\$6,000,000	1. Fulfills the majority of project goals. 2. Allows for analysis of some terrain features.	1. Requires research to extend the present state of the art to this specific application. (tracer studies, etc.) 2. Beyond the project's budget. 3. Would require additional computer software.
9. Develop an air quality model on the regional scale in more complex terrain where terrain features may include both hills and mountains.	\$6,000,000	1. Fulfills the majority of project goals. 2. Allows for analysis of some terrain features.	1. Requires research to extend the present state of the art to this specific application (tracer studies, etc.) 2. Beyond the project's budget. 3. Would require additional computer software.

<u>Option</u>	<u>Costs</u>	<u>Advantages</u>	<u>Disadvantages</u>
10. Develop an air quality model for a limited portion of the Flathead River Basin characterized by a single terrain type as for example the gently rolling hills in the southwest or the more rugged terrain in the north and east part of the Basin.	Not quantifiable	1. Fulfills most of the project goals.	1. Unattainable given present state of the art.
11. Develop an air quality model for a portion of the Basin involving mixed terrain types.	Not quantifiable	1. Fulfills most of the project goals. 2. Allows for analysis of some terrain features.	1. Unattainable given present state of the art.
12. Develop an air quality model for the entire Flathead River Basin.	Not quantifiable	1. Completely fulfills the project goals. 2. Allows for analysis in all areas of the Basin regardless of terrain.	1. Unattainable given present state of the art.

TABLE 8-A

General Meteorological Data Periods

<u>Monitoring Site</u>	<u>Date Period</u>
Glacier International Airport	Dec. 1979 - Nov. 1980
Ninepipe	Mar. 1981 - Feb. 1982
Polson	Mar. 1981 - Feb. 1982
Columbia Falls	Sep. 1978 - Aug. 1979
Bigfork	Jul. 1981 - Jun. 1982
Big Prairie (N. Fk. Flathead R.)	Mar. 1981 - Feb. 1982

TABLE 9-A

Meteorological Data Recovery and Source

Big Prairie (BP)

Monitoring Site

<u>Month/Year</u>	<u>Wind Speed</u> <u>Recovery(%)</u>	<u>Wind Direction</u> <u>Recovery(%)</u>	<u>Temperature</u> <u>Recovery(%)</u>	<u>Stability</u> <u>Recovery(%)</u>	<u>Mixing Height</u> <u>Recovery(%)</u>	<u>Source</u>
Nov/78 (Jan)	68	BP	97	97	100	GIA
Dec/78 (Feb)	39	BP	100	100	100	GIA
Mar/81	58	BP	47	100	100	GIA
Apr/81	85	BP	100	100	100	GIA
May/81	99	BP	100	100	100	GIA
Jun/81	99	BP	100	100	100	GIA
Jul/81	100	BP	94	90	100	GIA
Aug/81	95	BP	100	100	100	GIA
Sep/81	98	BP	81	100	100	GIA
Oct/80	74	BP	100	100	100	GIA
Nov/78	68	BP	100	100	100	GIA
Dec/78	32	BP	100	100	100	GIA

TABLE 9-B

Meteorological Data Recovery and Source

Columbia Falls (CF)

Monitoring Site

Month/Year	Wind Speed		Wind Direction		Temperature		Stability		Mixing Height	
	Recovery(%)	Source	Recovery(%)	Source	Recovery(%)	Source	Recovery(%)	Source	Recovery(%)	Source
Sep/78	100	CF	100	CF	100	GIA	100	GIA	100	GIA
Oct/78	97	CF	100	CF	99	GIA	61	GIA	100	GIA
Nov/78	77	CF	77	CF	100	GIA	100	GIA	100	GIA
Dec/78	45	CF	64	CF	100	GIA	100	GIA	100	GIA
Jan/79	91	CF	76	CF	100	GIA	97	NWS*	100	GIA
Feb/79	100	CF	100	CF	100	GIA	46	GIA	100	GIA
Mar/79	100	CF	100	CF	100	GIA	20	NWS	100	GIA
Apr/79	100	CF	97	CF	99	GIA	100	GIA	100	GIA
May/79	100	CF	100	CF	100	FIA	100	NWS	100	GIA
Jun/79	100	CF	100	CF	99	GIA	68	GIA	100	GIA
Jul/79	87	CF	90	CF	100	GIA	100	GIA	100	GIA
Aug/79	78	CF	78	CF	100	GIA	65	GIA	100	GIA

*NWS = Kalispell National Weather Service

TABLE 9-C

Meteorological Data Recovery and Source
Glacier International Airport (GIA)

Monitoring Site

Month/Year	Wind Speed		Wind Direction		Temperature		Stability		Mixing Height	
	Recovery(%)	Source	Recovery(%)	Source	Recovery(%)	Source	Recovery(%)	Source	Recovery(%)	Source
Jan/80	100	GIA	100	GIA	97	GIA/NWS*	97	GIA	100	GIA
Feb/80	100	GIA	100	GIA	100	GIA	86	GIA	100	GIA
Mar/80	91	GIA	91	GIA	100	GIA/NWS	90	NWS	100	GIA
Apr/80	100	GIA	100	GIA	100	GIA	100	GIA	100	GIA
May/80	100	GIA	100	GIA	100	GIA	81	GIA	100	GIA
Jun/80	99	GIA	99	GIA	99	GIA	67	GIA	100	GIA
Jul/80	100	GIA	100	GIA	100	GIA	91	GIA	100	GIA
Aug/80	100	GIA	100	GIA	100	GIA	100	GIA	100	GIA
Sep/80	100	GIA	100	GIA	74	GIA	100	GIA	100	GIA
Oct/80	97	GIA	98	GIA	100	NWS	99	GIA	100	GIA
Nov/80	84	GIA	85	GIA	100	GIA	83	GIA	100	GIA
Dec/79	100	GIA	100	GIA	100	GIA	100	GIA	100	GIA

*NWS = Kalispell National Weather Service

TABLE 9-D

Meteorological Data Recovery and Source

Big Fork (BF)

Monitoring Site

Month/Year	Wind Speed Recovery(%)	Source	Wind Direction Recovery(%)	Source	Temperature Recovery(%)	Source	Stability Recovery(%)	Source	Mixing Height Recovery(%)	Source
Jan/82	100	BF	99	BF	100	BF	100	GIA	100	GIA
Feb/82	74	BF	76	BF	74	BF	98	GIA	100	GIA
Mar/82	93	BF	93	BF	88	BF	100	GIA	100	GIA
Apr/82	32	BF	35	BF	32	BF	100	GIA	100	GIA
May/82	100	BF	79	BF	100	BF	100	GIA	100	GIA
Jun/832	52	BF	0	BF	52	BF	92	GIA	100	GIA
Jul/81	31	BF	35	BF	100	NWS	90	GIA	100	GIA
Aug/81	94	BF	94	BF	94	BF	100	GIA	100	GIA
Sep/81	74	BF	74	BF	74	BF	100	GIA	100	GIA
Oct/81	100	BF	100	BF	100	BF	100	GIA	100	GIA
Nov/81	100	BF	100	BF	100	BF	100	GIA	100	GIA
Dec/81	100	BF	100	BF	100	BF	100	GIA	100	GIA

*NWS = Kalispell National Weather Service

TABLE 9-E

Meteorological Data Recovery and Source

Polson (POL)

Monitoring Site

Month/Year	Wind Speed		Wind Direction		Temperature		Stability		Mixing Height	
	Recovery(%)	Source	Recovery(%)	Source	Recovery(%)	Source	Recovery(%)	Source	Recovery(%)	Source
Mar/81	71	POL	69	POL	70	NIN	84	NIN	100	NIN
Apr/81	68	POL	68	POL	52	NIN	80	NIN	100	NIN
May/81	81	POL	82	POL	59	NIN	100	NIN	100	NIN
Jun/81	98	POL	98	POL	98	NIN	88	NIN	100	NIN
Jul/81	100	POL	100	POL	100	NIN	83	NIN	100	NIN
Aug/81	62	POL	74	POL	73	NIN	81	NIN	100	NIN
Sep/81	92	POL	97	POL	97	NIN	97	NIN	100	NIN
Oct/81	85	POL	87	POL	87	NIN	97	NIN	100	NIN
Nov/81	100	POL	97	POL	100	NIN	67	NIN	100	NIN
Dec/81	51	POL	55	POL	16	NIN	92	NIN	100	NIN
Jan/82	100	POL	97	POL	97	NIN	37	NIN	100	NIN
Feb/82	100	POL	100	POL	100	NIN	100	NIN	100	NIN

TABLE 9-F

Meteorological Data Recovery and Source

Ninepipe (NIN)

Monitoring Site

Month/Year	Wind Speed		Wind Direction		Temperature		Stability		Mixing Height	
	Recovery(%)	Source	Recovery(%)	Source	Recovery(%)	Source	Recovery(%)	Source	Recovery(%)	Source
Mar/81	100	NIN	100	NIN	70	POL	84	NIN	100	NIN
Apr/81	98	NIN	100	NIN	52	POL	80	NIN	100	NIN
May/81	100	NIN	99	NIN	59	POL	100	NIN	100	NIN
Jun/81	99	NIN	97	NIN	98	POL	88	NIN	100	NIN
July/81	100	NIN	99	NIN	100	POL	83	NIN	100	NIN
Aug/81	86	NIN	86	NIN	73	POL	81	NIN	100	NIN
Sep/81	50	NIN	50	NIN	97	POL	97	NIN	100	NIN
Oct/81	71	NIN	70	NIN	87	POL	97	NIN	100	NIN
Nov/81	96	NIN	96	NIN	100	POL	67	NIN	100	NIN
Dec/81	100	NIN	100	NIN	16	POL	92	NIN	100	NIN
Jan/82	100	NIN	97	NIN	97	POL	37	NIN	100	NIN
Feb/82	100	NIN	100	NIN	100	POL	100	NIN	100	NIN

TABLE 10-A

Emission Rates (g/sec)
Proposed Cabin Creek Coal Mine

Sulfur Dioxide

21.46

Particulates

62.24

TABLE 11-A

North Fork Box Model Results
Predicted Increases in Five Day and Twenty Four Hour Concentration (ug/m³)
from Proposed Cabin Creek Mine

Five Day Average
Box Number

	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
Particulates						
H = 200 L = 0%	19.9	0.0	0.0	0.0	0.0	0.0
H = 200 L = 10%	19.3	0.0	0.0	0.0	0.0	0.0
H = 800 L = 0%	18.6	0.0	0.0	0.4	0.0	0.0
Sulfur Dioxide						
H = 200 L = 0%	7.1	0.0	0.0	0.0	0.0	0.0

Maximum Twenty Four Hour Average

	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>6</u>
Particulates						
H = 200 L = 0%	58.1	10.0	2.9	0.8	10.1	16.0
H = 200 L = 10%	46.3	4.7	0.0	0.0	0.0	0.0
H = 800 L = 0%	33.2	8.7	8.1	9.0	1.3	0.0
Sulfur Dioxide						
H = 200 L = 0%	17.5	0.6	0.0	0.0	0.0	0.0

TABLE 12-A

North Fork Valley Model Results
 Predicted Increases in Annual Concentration ($\mu\text{g}/\text{m}^3$)
 from Proposed Cabin Creek Coal Mine

<u>Maximum Predicted</u>	<u>Sulfur Dioxide Class I Increment</u>	<u>Class II Increment</u>	<u>Maximum Predicted</u>	<u>Particulates Class I Increment</u>	<u>Class II Increment</u>
2.2	2	20	20.2	5	19

TABLE 13-A

Hypothetical North Fork Gas Flare
 Sulfur Dioxide Emission Parameters

<u>Source</u>	<u>Emission Rate (g/sec)</u>	<u>Stack Height (m)</u>	<u>Stack Diameter (m)</u>	<u>Gas Velocity (m/sec)</u>	<u>Gas Temperature (deg K)</u>
Well #1	6.80	9	0.4	20.0	1273
Well #2	3.60	9	0.3	20.0	1273

TABLE 14-A

North Fork Valley and Box Model Results
 Annual and Twenty Four Hour Sulfur Dioxide Concentrations ($\mu\text{g}/\text{m}^3$)
 Hypothetical Gas Flares

	<u>Predicted Maximum</u>	<u>2nd High</u>	<u>Class I Increment</u>	<u>Class II Increment</u>
Annual (VALLEY)	19.8	16.5	2	20
24-hour maximum (BOX)	30.5		5	91

TABLE 15-A

ISCLT Model Results, Run 1
Annual Particulate Concentrations (ug/m³)
Measured vs. Predicted

<u>Location</u>	<u>Measured</u>	<u>Predicted</u>
Columbia Falls Airshed		
Anders	132	391
NAAC	27	15
Ninepipe Airshed		
Ninepipe	26	1
Polson Airshed		
Polson	45	20
Kalispell Airshed		
Universal Athletic	99	54
Evergreen	-	274
Airport	61	16
Bigfork Airshed		
Bigfork	-	93

TABLE 16-A

ISCST Model Results, Run 1
 Kalispell Airshed
 Twenty Four Hour Concentrations ($\mu\text{g}/\text{m}^3$)
 Measured vs. Predicted

	<u>Julian Day</u>	<u>Measured</u>	<u>Predicted</u>
Jan. 1980	4	137	31
	10	55	25
	16	62	83
	22	-	79
	28	123	58
Feb. 1980	34	60	8
	40	63	57
	46	37	40
	52	126	43
	58	-	110
Mar. 1980	64	-	57
	70	-	-
	76	141	5
	82	-	113
	88	197	7
Apr. 1980	94	192	17
	100	59	4
	106	118	26
	112	126	25
	118	87	81
May 1980	124	82	26
	130	107	28
	136	150	43
	142	-	17
	147	138	-
Jun 1980	154	95	12
	160	66	17
	166	82	23
	172	95	1
	178	68	-
July 1980	184	86	46
	190	112	14
	196	65	32
	202	63	21
	208	137	19
Aug 1980	214	114	4
	220	-	14
	226	65	38
	232	82	9
	238	71	23
	244	72	24

TABLE 16-A (Cont.)

	<u>Julian Day</u>	<u>Measured</u>	<u>Predicted</u>
Sep 1980	250	-	68
	256	202	26
	262	108	-
	268	117	18
	274	-	-
Oct 190	280	130	43
	286	73	74
	292	67	46
	298	92	53
	304	91	44
Nov 1980	310	83	-
	316	85	67
	322	-	95
	328	148	65
	334	52	55
Dec 1980	340	78	2
	346	48	43
	352	202	82
	358	40	32
	364	296	46

TABLE 17-A

Summary of ISCST Model Results, Run 1
 Twenty Four Hour Concentration ($\mu\text{g}/\text{m}^3$)
 Average Measured Value vs. Average Predicted Value

<u>Monitor Location</u>	<u>Average⁺</u>		<u>Maximum</u>	
	<u>Measured</u>	<u>Predicted</u>	<u>Measured</u>	<u>Predicted</u>
Airport	62	75	309*	147*
Univ. Athletic	103	39	296*	113*
Ninepipe	20	2	55*	6*
Polson	45	2	83*	13*
NAAC	30	18	64*	57*
Anders	142	68	484*	298*
Evergreen	68	105	169*	295*
Bigfork	33	0	109	0

*Occurred on different days

+Average concentration for days that were modeled

TABLE 18-A

ISCLT Model Results, Run 2
 Annual Concentrations ($\mu\text{g}/\text{m}^3$)
 Measured vs. Predicted

<u>Location</u>	<u>Measured</u>	<u>Predicted</u>
Columbia Falls Airshed		
Anders	132	38
NAAC	27	12
Ninepipe Airshed		
Ninepipe	26	1
Polson Airshed		
Polson	45	67
Kalispell Airshed		
Universal Athletic	99	65
Evergreen	-	119
Airport	61	124

TABLE 19-A

Residual Measure of Accuracy
Annual Concentrations

<u>Monitor Location</u>	<u>Residual-Run 1</u>	<u>Residual-Run 2</u>
Anders	-259	94
NAAC	12	15
Ninepipe	25	25
Polson	25	-22
Univ. Athletic	45	34
Airport	45	-63
Bigfork	-100	--

TABLE 20-A

Residual Measure of Accuracy
Twenty Four Hour Concentrations

<u>Monitor Location</u>	<u>Space and Time</u>		<u>Space</u>	
	<u>Maximum</u>	<u>2nd High</u>	<u>Maximum</u>	<u>2nd High</u>
Anders	293	265	77	9
NAAC	45	21	6	6
Ninepipe	43	41	50	49
Polson	68	76	70	68
Univ. Athletic - Run 1	250	176	183	92
Airport - Run 1	214	171	162	98
Evergreen - Run 1	107	92	-126	-154
Bigfork	109	84	109	84
Univ. Athletic - Run 2	294	200	268	177
Airport - Run 2	301	231	301	225
Evergreen - Run 2	164	128	144	121

TABLE 21-A

Performance Measure for Gross Variability
Twenty Four Hour Particulate Concentrations

<u>Monitor Location</u>	<u>Mean Absolute Residual</u>	<u>Mean Square Error (MSE_d)</u>
Anders	95	15,768
NAAC	14	320
Ninepipe	18	510
Polson	40	1,918
Univ. Athletics - Run 1	71	7,853
Airport - Run 1	53	4,975
Evergreen - Run 1	79	10,007
Univ. Athletics - Run 2	98	12,226
Airport - Run 2	60	6,740
Evergreen - Run 2	62	5,170

TABLE 22-A

Student's "t" Test Results

<u>Monitor Location</u>	N	<u>Runs Test</u>		<u>Deg. Freedom</u>	T	T Critical
		<u>Passes</u>	<u>Pass/Fail</u>			
Anders	39	18	Pass	76	4.071	1.995
NAAC	40	19	Pass	78	2.910	1.994
Ninepipe	29	11	Pass	56	6.769	2.004
Polson	40	9	Fail	78	--	--
Airport - Run 1	50	20	Pass	98	2.079	1.987
Univ. Athletic - Run 1	47	24	Pass	92	8.365	1.989
Evergreen - Run 1	27	9	Pass	52	2.041	2.011
Airport - Run 2	50	22	Pass	98	7.287	1.987
Univ. Athletic - Run 2	47	20	Pass	92	12.850	1.989
Evergreen - Run 2	27	8	Pass	52	8.437	2.011

TABLE 23-A

Linear Regression and Correlation Results

<u>Site</u>	<u>a*</u>	<u>b*</u>	<u>r</u>
Anders	0.195	128.700	0.16
NAAC	21.359	0.314	0.33
Evergreen - Run 1	83.500	- 0.150	-0.31
Polson	35.050	3.003	0.52
U. Ath. - Run 1	102.170	0.029	0.01
Ninepipe	14.570	2.630	0.27
Airport - Run 1	97.660	- 0.469	-0.23
Bigfork	0.000	33.000	0.00
Evergreen - Run 2	66.075	0.144	0.03
U. Ath. - Run 2	107.502	- 0.793	-0.10
Airport - Run 2	6.058	48.717	0.18

*Where predicted = a x observed + b

PROJECT SUMMARY

The air quality portion of the Flathead Basin Environmental Impact Study has provided valuable information which will be very helpful in planning future economic development and land use options within the Basin. The project successfully accomplished the first three of the five goals established at the start of the project; namely, (1) to quantify the existing air quality of the basin; (2) to identify and quantify the existing sources of emissions within the Basin; and (3) to quantify the meteorology of the Basin at both low and high altitudes. The fourth and fifth goals (to develop the capability to assess the effects of man's activities upon the air quality of the Basin and to develop guidelines to protect and enhance the air quality of the Basin) were only partially successful.

The existing air quality of the Basin was quantified by the intensive network of particulate and visibility monitors which were operated throughout the Basin. This data will serve as an excellent baseline to gauge the air quality effects of future developments and land use changes.

The nonpoint source emission inventory conducted as part of the study was an excellent effort to quantify emissions of sulfur dioxide and particulates throughout the Basin. The nonpoint source inventory and the Air Quality Bureau's point source emission inventory provide a good understanding of the emissions and types of sources presently affecting the Basin.

The meteorological data gathered has filled a major data void, especially in regard to upper level winds. In the past upper level wind information had to be obtained from National Weather Service offices in Great Falls and Spokane. Neither of these locations is typical of the Flathead Basin. The unique nature of the Basin's surface winds was characterized by the six surface wind systems

located in the area. By processing Basin wind data into STAR decks and representative hourly data, the project has created an extremely valuable tool which can serve as a Basin specific input to any common diffusion model.

Although the actual performance of the models was less than expected, they did perform well in critical areas. The Box and VALLEY models used in the North Fork valley performed very well. This is extremely important in light of the proposed Cabin Creek Mine. The other models utilized in the other airsheds generally performed poorly due to their inability to handle fugitive dust and other area source emissions. To improve model performance in regard to the area sources would require a much more intensive area source inventory (perhaps 100 meter grids) and/or drastic model refinements. Both of these options would be extremely expensive. Although it is disappointing that the impact from area source emissions could not be adequately predicted, it is encouraging that point source emissions were reliably modeled.

The final goal of the project was to develop guidelines to protect and enhance the air quality of the Basin. The Air Quality Bureau offers the following general guidelines to accomplish this goal:

1. All new significant point sources of air pollutants should undergo a preconstruction review as prescribed in the Federal Prevention of Significant Deterioration (PSD) regulations. The importance of preconstruction and post construction air monitoring cannot be over emphasized.
2. It is essential that the State of Montana, the Environmental Protection Agency and the Salish Kootenai tribe continue to cooperate on developing air quality regulations which are consistent.

3. The State of Montana, EPA, and Flathead Basin agencies and organizations should continue to communicate with the British Columbia government in an effort to minimize possible air quality impacts from the proposed Cabin Creek Mine.
4. A source of funding should be found to operate a remote air monitoring station in the North Fork between Polebridge and the U.S.-Canadian border. Operation of a site without commercial power available is beyond the budget of the Air Quality Bureau. A reliable monitoring site in the North Fork would provide better quality meteorological data for the winter months, track the air quality impacts of the Cabin Creek mine, and help discover the source of the sulfates at Polebridge.
5. Future significant changes in land use should be identified and monitoring efforts should be initiated to assess the air quality impacts.
6. Population based trends such as residential wood combustion should also be identified and monitored to assess the air quality impacts.
7. An effort should be made to further define the particulate problem in Kalispell and mitigate the primary causes.
8. Continue to investigate and apply new technology for modeling fugitive emissions such as the chemical mass balance technique.

Each of these general guidelines will require detailed protocols to assure they are carried out. The Air Quality Bureau will continue to administer the PSD program in the Basin and is deeply involved in assisting the Salish Kootenai tribe in the development of an air quality program on the Flathead Reservation. The AQB plans to embark upon a chemical mass balance study of the Kalispell particulate problem within the next year. Although the Air Quality Bureau is involved in accomplishing all of these recommendations, the responsibility for accomplishing them also lies with local governments and the Flathead Basin

Commission which the State Legislature funded until July, 1985. This is especially true in regard to identifying developments or land use changes which might threaten the air quality of the Flathead Basin.

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